



PHD

**An Investigation into Improving the Sustainability of Small and Medium Size Enterprises
Rationalised Life Cycle Assessment Approaches in Service Industries**

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An Investigation into Improving the Sustainability of Small and Medium Size Enterprises

**Rationalised Life Cycle Assessment Approaches in
Service Industries**

Charmaine Yasmin Martin

A thesis submitted for the degree of Doctor of Philosophy

University of Bath
Department of Mechanical Engineering
July 2016

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Abstract

This research aims to determine whether rationalised life cycle assessment approaches (RLCAAs) are useful and suitable techniques to measure the environmental impacts of small and medium size enterprises (SMEs) from service industries. RLCAAs are simplified; less resource intensive techniques; that do not measure exclusively carbon dioxide equivalents (CO₂e) but consider the wider environmental impact details. There is limited research on suitable techniques that measure the wider environmental impacts of service industry SMEs; however, with increasing pressures on accountability, it is important for businesses to recognise these impacts.

This study provides an interdisciplinary assessment on such SMEs by using a range of appraisal tools and approaches and using primary data collected from owner-managers and employees. The results suggest SMEs do not adopt a strategic approach to environmental matters and that the respondent companies produce on average 70t CO₂e a year.

A qualitative assessment undertaken from a roundtable discussion found amongst employees concern, that using CO₂e only, as a quantifying metric to gauge impacts, loses wider impact details. Life cycle assessments seek to acknowledge wider environmental impact details, are not promoted to SMEs because they are resource intensive and too complex, to be of practical use. The criticisms are pertinent relative to a '*cradle to grave*' quantitative assessment. However, in terms of RLCAAs their specific application and benefits to SMEs is unknown

Two RLCAAs were configured and tested upon three-service industry case studies; a packing, film and online distance learning establishment. One a magnitude, the other a pragmatic approach differed in the use of qualitative criteria; demonstrated by similar findings, with transport, energy and equipment identified as core emitters, less time consuming approaches can be used effectively by SMEs. In conclusion, both RLCAAs would prove useful at raising environmental awareness, assessing aspects and highlighting impacts thereby, potentially improving the sustainability of SMEs.

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“We don’t receive wisdom; we must discover it for ourselves after a journey that no one can take for us or spare us”

I took a journey but could not have completed it without the support of many; thank you....

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Glossary

List of notations and abbreviations

Abiotic	Non-living elements: physical or chemical components within ecosystems and includes amongst others, climate, pH or gases:
Aspect	Aspect: elements of a company's services, products or activities that interacts with the environment; for instance the use of resources, energy and materials
B&NES	Bath and North East Somerset: a unitary authority created in 1996, administers the functions of local government in Bath and North East Somerset
Biotic	Living elements: organisms within ecosystems for instance, plants, bacteria or animals
CAT	Credit Accumulation & Transfer Scheme: educational credits accrued from modular courses to facilitate movement between study programmes and institutions in the UK
CO₂ eq.	Carbon dioxide equivalent: used to describe global warming potential caused by a greenhouse gas in terms of carbon dioxide
CO₂e	Carbon dioxide equivalent: see above
Customer-facing	Customer-facing: refers to a company that conducts most of its business activities by direct physical contact with its customer who buys the service
Defra	Department for the Environment Food and Rural Affairs: UK government department whose responsibilities include safeguarding the environment; food standards; supporting agriculture, fisheries and the rural economy
DECC	Department of Energy and Climate Change: government department established in 2008 responsibilities include energy security, renewable energy and mitigating climate change
EA	Environment Agency: UK public body established in 1996 responsible for improving and protecting the environment
E-business	E-business: refers to a company that conducts most of its business processes and activities online, electronically through the internet, with no direct physical contact with its customers
EMS	Environmental Management System: a framework implemented by an enterprise to manage environmental impacts for instance, ISO 14000 or BS 8555
Envision	Envision: a RDA funded programme delivered in three phases from 2002-2009 focused upon improving the environmental performance of SMEs
EU	European Union: a collective term to denote the political and economic union currently of 28 states

FSB	Federation of Small Businesses: established in 1974; a non-political, non-profit making campaigning organisation that promotes the interests of small companies
FTE	Full time equivalent: a term used to determine comparable workloads with a full time employee as the reference
GHG	Greenhouse Gas: gases, which absorb and release radiation within the thermal infrared band, giving rise to the greenhouse effect that causes global warming
(H)	Hierarchical: refers to a perspective in which inclusion of data and facts are substantiated by scientific and political organisations; the default version setting recommended for use with SIMAPRO
ICT	Information and Communication Technology: integrated audio visual, computer and telephone networks; but colloquially used to denote computers their peripheral hard and software
IEMA	Institute of Environmental Management and Auditing: a professional membership organisation catering for the needs of individuals employed within the environmental and sustainability professions
Impact	Impact: changes in the environment that results from the company's aspects; for instance, land, water or air pollution
IYRE	Improve Your Resource Efficiency: a follow on funded programme from Envision focusing on improvements to environmental performance among SMEs that ran from 2009-2013
kW	kilowatt: unit attributed to electric power equivalent to 1000 watts (W)
kWh	kilo watt-hour: the unit of energy spent from power consumption during an hour with 1kWh equivalent to 3.6MJ
LCA	Life Cycle Assessment: method of assessing environment aspects for products or services; to determine their impacts and depending upon the system from the inception of the product or service to its demise
LCT	Life cycle thinking: used to denote a holistic concept that promotes environmentally proactive behaviour amongst enterprises
Low-hanging	Low-hanging: an informal terms referring to easy and simple tasks or activities, in this instance, environmental related courses of action, that are undertaken easily and quickly but are not seen as part of a wider range of changes or solutions to a problem

ODL	Online distance learning: Learning that is undertaken using computers or other electronic devices connected to the internet
Owner-managers	Owner-managers: individuals within the company who have a controlling ownership either alone, with family members or with a few partners; involved in the main decision-making
PET	Polyethylene terephthalate: a thermoplastic polymer resin i.e. a plastic used in the manufacture of food and drink containers
PP	Polypropylene: a thermoplastic polymer resin i.e. a plastic whose high and low physical and chemical properties makes it suitable for a number of applications where toughness and flexibility are needed
RLCAA	Rationalised Life Cycle Assessment Approaches: refers to a simplified and less resource intensive LCA approach or technique that addresses environmental aspects and measures wider environmental impact details of a service and depending upon the system from the inception of the service to its demise. The approaches used can be quantitative, semi-quantitative or qualitative where parameters are primarily decided, from readily available data from the SMEs, databases or literature
RDA	Regional Development Agency: public body created to foster economic development from 1998 to 2012
Scope 1	Direct emissions: emissions resulting from sources controlled or owned by the SME, e.g. emissions from transport or equipment
Scope 2	Indirect emissions: emissions produced or generated by the SME usually from purchased electricity, but also from heat or steam
Scope 3	Other indirect emissions: emissions resulting from activities of the SME but from sources that they do not control or own e.g. outsources activities for instance waste disposal
SIC	Standard Industrial Classification: used to group businesses according to their economic activity
SMEs	Small and Medium Sized Enterprises: usually businesses, which have fewer than 250 employees
t	tonne: metric unit of weight and equivalent to 1,000 kg
t(hr)	t(hr): period of time in hours
W	Watt: unit of power

Chapter 1

Introduction

This chapter provides background to the study, the research aim and objectives. The organisation of the thesis is outlined, in addition to a diagrammatic illustration of the structure, indicating in which chapters the objectives are addressed and met.

1.1. Background

Small and Medium Sized Enterprises (SMEs), are considered as channels for economic growth and employment (ECOTEC, 2000; Bititci, *et. al.*, 2012). The importance of SMEs, defined in the UK as employing fewer than 250 people, derives from the influence they exert cumulatively at a global and national level on the economy and environment (Vickers, *et. al.*, 2009). SMEs account for 95% of the global business population (OECD, 2005) and reportedly contribute 70% towards all global environmental pollution (Revell, Stokes & Chen, 2010).

At a national level, in terms of the United Kingdom (UK) economy, SMEs account for 99.9% of the 5.2 million private sector businesses in the UK (BIS, 2014; Rhodes, 2015). Moreover, the SME sector is considered vital to the UK economy providing employment for ~59% of the private sector and contributing to ~50% of the country's gross domestic product (GDP) (Ward & Rhodes, 2014), and reportedly producing 60% of the UK's total carbon emissions (Aragon-Correa, *et. al.*, 2008).

One of the main problems with SMEs however, is their reported lack of interest towards environmental issues (Connell, 2008, p.5). The lack of interest is demonstrated by their reluctance to engage in environmental improvement initiatives (Tilley, 1999a; Revell & Rutherford, 2003) in spite of their contributions towards global and national pollution levels outweighing the total impacts of larger businesses (Hillary, 2000; EA, 2003).

The lack of interest expressed by SMEs to environmental issues has become increasingly important, as the environment has become more prominent. The reluctance of this sector to improve environmental performance has proved problematic in integrating SMEs within the wider sustainable development and low carbon debates (Vickers, *et. al.*, 2009). The influence of SMEs on the environment will however, potentially increase as growth is predicted because of outsourcing, self-employment, franchising opportunities and flexible production methods (Stokes & Wilson, 2006).

Recent figures show an increase in the UK business population, being driven by the rise in the numbers of SMEs (BIS, 2014). The rise in the number of SMEs coupled with carbon reduction targets set on a trajectory of 80% reduction by 2050 and 34% by 2020 from the baseline year, 1990 (HMG, 2011); the role of smaller businesses to take responsibility and action will become increasingly expected (Cassells & Lewis, 2011). Subsequently, the growth and cumulative impact of the sector means there is a research need to address the continued environmental impacts of SMEs.

Although, the growth of the SME sector is increasing, it is not consistent among the economic or industrial divisions (Slattery, 2009). Industry can be classified into three main economic sectors referred to as primary, secondary and tertiary (UN, 2008). The primary sector of the economy refers to those businesses that extract natural resources and includes for instance, agricultural and mining (Bailey, 2000). The secondary sector represents industries that process the raw materials from the primary sector into products and goods, for instance furniture production or food processing (Bailey, 2000). The tertiary or service sector entails selling the primary and secondary economic sectors goods and products and the selling of services and skills (Slattery, 2009). These types of services can include financial, education, entertainment, consultancy and ICT (information and communication technologies) (Slattery, 2009). The forecast within western economies however, is for the continued shift from primary and secondary based economies towards the service sector (WCED, 1987).

One of the challenges for service sector SMEs is therefore, to minimise their environmental impacts and reduce their pollution levels. The drivers for and barriers to environmental activity has been discussed extensively in the literature for example by Holland & Gibbon, 1997; Tilley, 1999a; Rutherford, Blackburn & Spence, 2000; Hillary, 2000; Revell, 2005; Revell & Blackburn, 2007; Revell, Stokes, & Chen, 2010; Cassells & Lewis, 2011; where they are presented generally cross-sector and applicable to all SMEs or upon limited service industries.

It has been suggested to *drive* SMEs environmental activity a strategic approach is required (Brio, Fernandez & Junquera, 2007) as opposed to *ad hoc* actions (Schaper, 2002; Simpson, Taylor & Barker, 2004; Revell, Stokes & Chen, 2010). Strategic approaches have been cited as adopting an Environmental Management System (EMS), writing an environmental policy or stakeholder communication each of which have been extensively researched (Bianchi & Noci, 1998; Millard, 2011). One strategic long-term approach would be the adoption of life cycle thinking (LCT). Life cycle thinking for a business entails in essence considering the product or service in terms to its environmental impacts from the *cradle to the grave* (Lewis & Demmers, 1996).

A strategic approach implies long-term, an investment of some resources, integration, continuity and the commitment of management to achieve sustainable environmental results. The counter to strategic is an *ad hoc* approach, which implies short term, limited integration, lack of continuity as efficiency gains are dissipated and reliance on a few individual members of staff. There have been a number of Government and EU funded programmes targeted at SMEs in the South West, including Envision (2002-2009) and IYRE (Improve Your Resource Efficiency) (2009-2013) that have focused on the *low-hanging* options to reduce environmental impacts.

Life cycle assessment techniques and approaches have been used extensively and more recently by larger corporate businesses in relation to product design, innovation and marketing (Frankl & Rubik, 1999). The assessment techniques and approaches are used to assess the environmental aspects, the inputs and outputs, and the associated effects that the product or service has during its life cycle on the environment (ISO, 2006a). In terms of SMEs from the service sector, these assessment techniques and approaches are not seen as strategic instruments to highlight potential environmental aspects in the performance of their service, nor are they seen as presenting opportunities to reduce their environmental impacts.

The tools presented to SMEs generally to assess their environmental impacts are problematic because the databases lack transparency and are single issue focused (Padgett, *et al.*, 2008; Heidrich & Tiwary, 2013). Established LCA approaches and techniques are not considered useful because they are resource intensive in terms of time, expense and data and are regarded as being too complex, to be of practical use (Frankl & Rubik, 1999; Junnila, 2006b). The criticisms are pertinent in relation to a full *cradle to grave* quantitative assessment. In terms however, of the less quantified approaches and techniques the criticisms are unqualified because their underutilisation specifically by service sector SMEs and application is unknown.

1.2. Research aim and objectives

The study, within the context of the background and in accordance with the sponsors' focal themes of sustainability, SMEs and LCA, assesses the effectiveness of simplified LCA techniques; rationalised life cycle assessment approaches (referred to as; RLCAAs), to measure the environmental impacts of SMEs from established service industries. The main aim of the research therefore is as follows:

Aim: To determine whether rationalised life cycle assessment approaches are useful and suitable techniques to measure the environmental impacts of SMEs from service industries

To address the research aim a number of objectives were determined and are as follows:

Objective I: To identify the type of data available from owner-managers of service industry SMEs that can be used to report the amount of greenhouse gas (GHG) emissions being produced

Objective II: To establish the views and opinions of service industry employees from SMEs to measuring, managing and reporting GHG emissions

Objective III: To assess the environmental aspects on selected SME case studies using rationalised life cycle assessment approaches

Objective IV: To compare and contrast the findings from the rationalised life cycle assessment approaches to determine their suitability for service industry SMEs

Objective V: To draw conclusions from the analysis and highlight areas for further research

1.3. Organisation and structure of the thesis

The thesis is set out as follows. In Chapter 2, a review of the literature is presented. Chapter 2 serves to place the study within the context of previous work, identifying the knowledge gaps and highlighting where this research assists with filling the gaps. In Chapter 3, the research approaches are outlined. The interdisciplinary nature of the research and the juxtaposition of science and social science research strategies needed explanation to the decisions underpinning the approaches to recruiting SMEs, conducting a roundtable discussion, the compilation and distribution of an online survey and the two RLCAA trialled on three service industry SMEs.

In Chapter 4, results from owner-managers in service industry SMEs who responded to an online survey and employees who participated in the roundtable discussion are presented thereby meeting *Objectives I and II* respectively. In Chapter 5, the three service industry case studies upon which the RLCAAs were applied are presented to give background and context to the results in Chapters 6 and 7 thereby, addressing *Objective III*. The discussion, in Chapter 8, synthesises the findings from the case studies thereby meeting *Objective IV*, considers the implications of said results and the limitations of the work presented. The final chapter, Chapter 9, is reserved for conclusions, recommendations and further work, and addresses *Objective V* (see Figure 1.1.).

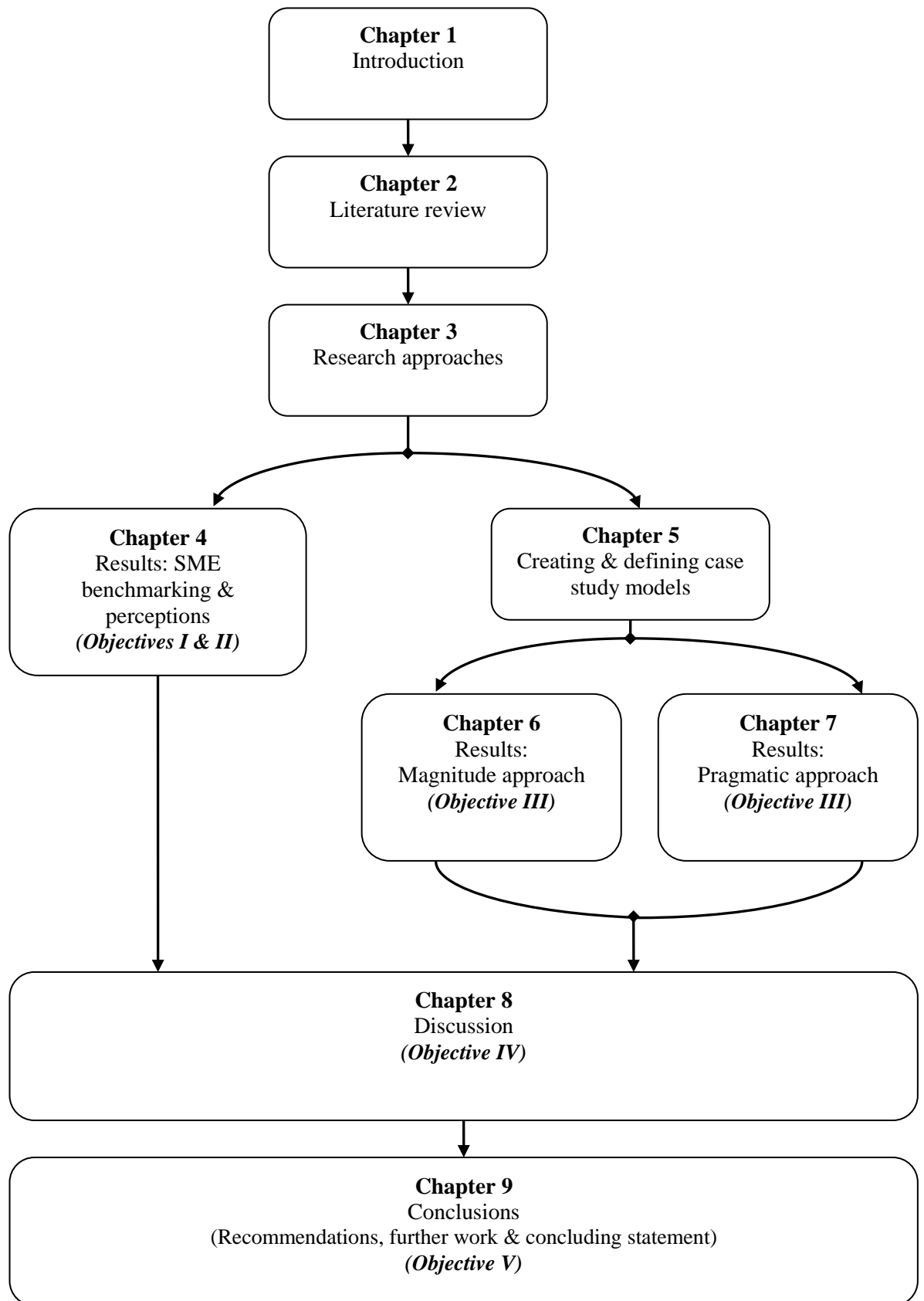


Figure 1.1: Diagrammatic illustration of the thesis structure

Chapter 2

Literature Review

This chapter reviews literature pertinent to small and medium-sized enterprises (SMEs), in terms of their relationship to the environment; identifying knowledge gaps in the literature that this research aims to fulfil. The chapter highlights the differing definitions attributed to SMEs; establishes the importance of service industries; explores the UK government's commitment to climate change and the potential role of SMEs in achieving the targets. The environmental impacts created by SMEs and the accounting tools and methods that can potentially be used by small businesses are evaluated and the gaps in knowledge further identified.

The results from a pilot study are reported, providing secondary evidence for that presented in the literature, and the research gaps. Finally, life cycle based approaches are explored as a means of evaluating the environmental aspects and impacts of services associated with service industry SMEs to fill the discovered gaps in knowledge.

2.1. Background

An investigation into improving the sustainability of SMEs needs an understanding of the term and its relationship to businesses. This is problematic because sustainability is broad (Kates, Parris & Leiserowitz, 2005; Maude, 2014); abstract (Birdsall, 2014); complex (Amini & Bienstock, 2014) and no absolute definition exists (Ahern, 2015). Sustainability however, as a term can be derived from the concept sustainable development and can be considered as being synonymous, with sustainable development (Birdsall 2014; Isaksson *et al.*, 2015). Accordingly, sustainability can be derived from the Brundtland definition where the notion of sustainable development is, the current generation should live in a manner that will not compromise the resources for future generations (Brundtland *et. al.*, 1987).

In terms of a business, the triple bottom line (TBL) focusing on the balance between environmental, economic and the business' social performance affords parity to sustainable development and its three pillars, environmental, economic and social (Elkington, 1998). To achieve a full sustainable state all three pillars need to be integrated within a business, organisation or corporation (Sitarz, 2008). In essence, this means a business from product input to distribution needs to be powered by a renewable energy; the product or service needs to be created so it enhances the natural world and is completely reused, the way nature reuses material (Sitarz, 2008). To achieve a full sustainable state is the ideal however, determining a business consensus for the economic and social parameters is developmentally problematic.

One pillar of noticeable and continual growing concern is the environment. A logical starting point in considering improving the sustainability of SMEs therefore, is the impact of businesses on the environment in relation to “*what gets measured gets done*” (Behn, 2003). The effect of businesses on the environment has been acknowledged in the literature where issues of waste generation and disposal, water availability, pollution and climate change has received attention. (UNEP, 2002). The focus has been upon larger businesses and corporations as seen by legislation and regulations, who are seen as the main consumers of energy and raw materials and the major causes of waste and pollution (Moss *et. al.*, 2008). The overlooking of SMEs generally, gives the impression that the sector is environmentally benign although empirical evidence is sparse, as environmental programmes had tended to focus on businesses that were larger (Mir & Feitelson, 2007).

2.2. Small and medium size enterprises (SMEs)

There is no single global standard definition of what constitutes a SME (Gibson & van der Vaart, 2008; Fisher *et al.*, 2009). For instance, in Denmark the term is defined as a company having fewer than or equal to 100 employees; in Australia, fewer than or equal to 200 employees and in the USA up to 500 employees (Senderovitz, 2009). The UK, as part of the EU, Recommendation 2003/361/EC, is applied. The definition used to determine whether a company is an SME in the EU therefore, considers the following, the number of employees, turnover and/or the balance sheet total (Commission Recommendation 2003/361/EC) (see Table 2.1) and a percentage holding value linked to a partner or other enterprise (Article 3.1. Commission Recommendation 2003/36/EC) (EC, 2003a). In terms of employees, in the UK a SME is a term typically used to describe a business that employs fewer than 250 employees.

Table 2.1: Main category thresholds used to determine SMEs

Size and category of business	No. of employees	Annual turnover (€)	Balance sheet totals (€)
Micro	<10	≤2 million	≤2 million
Small	<50	≤10 million	≤10 million
Medium	<250	≤50 million	≤43 million

Source: EC, 2003b; EC, 2005

The EU acknowledges the differences from larger businesses in relation to quantitative parameters as seen by employee numbers, turnover, and balance sheet totals. The features of SMEs, however, also, differ from larger businesses as summarised in Table 2.2.

Table 2.2: Features of SMEs compared to large companies

SMEs (<250 employees)	Large companies (>250 employees)
Small customer base and narrow product range	Large customer base and products
Limited resources (finance) and capabilities (specialist staff)	Larger resources and capabilities
Decentralised, informal and a flat organisational structure	Centralised and formal hierarchical organisational structure
Senior management positions held by the founders, relatives and/or family therefore, strong owner influence	Ownership and control in the hands of a board and a head
Sub-contractors	Contractors
Minimum level of income	Maximise profits
Limited performance monitoring	Performance monitored by shareholders
Niche products and services	Standardised product or service
Limited research and development (R&D)	R&D likely to be undertaken and funded
Innovations more likely	Introduction of new innovations restricted
Changes in the structure of the organisation likely as less commitment to existing products and practices	Changes in the evolutionary stages of the organisation unlikely
Informal trust-based relationships reliant upon personal contacts	Formal relationships under reliant upon contracts
Price takers from lack of control over business environment	Price influencers

Sources: van Hoorn, 1979; Brooksbank, 1991; MacGregor *et al.*, 2002; Vickers, *et. al.*, 2009

Subsequently, the differing structural contexts mean it is important to understand that SMEs are not small versions of larger firms (O'Regan, Ghobadian & Galleary, 2006) with operational and procedural differences potentially influencing decisions, views and opinions. Accordingly, any in-depth research on SMEs needs to garner the views and opinions of employees and their employers to bring a holistic understanding to a study.

2.3. Service industries

There has been an increase in the overall business population, driven by a 41% rise in the numbers of SMEs between 2000 and 2013 (BIS, 2013). However, not all industrial sections within the classification of businesses have experienced increases (Jones, 2013, UKSIC, 2007). While, employment in the service industries had increased by 85% in 2012; production and agricultural industries had decreased by 35% and 4% from their 1948 levels respectively, to 10% and less than 1% in 2012 (Jones, 2013). The increasing growth of service industries, which include many divisions (see Table 2.3); the lack of research data for sections within the index on their environmental impacts and the UK government's commitments to reducing emissions within the context of climate change means businesses included in the service industries cannot be ignored.

Table 2.3: Service industries with UK SIC sections as detailed in the index of services

Service industries	UK SIC
Wholesale & retail trade; repair of motor vehicles & motorcycles	G
Transportation & storage	H
Accommodation & food service activities	I
Information & communication	J
Financial & insurance activities	K
Real estate activities	L
Professional, scientific & technical activities	M
Administrative & support service activities	N
Public administration & defence; compulsory social security	O
Education	P
Human health & social work activities	Q
Arts, entertainment & recreation	R
Other service activities	S
Activities of households as employers	T

Source: Adapted from: Jones, 2013; UKSIC, 2007

2.4. UK government commitments to climate change

The UK government has recognised climate change and the threat of global warming by acknowledging the need to reduce anthropogenic green house gas (GHG) emissions; through International, European and National commitments. These commitments range from the Kyoto Protocol (1998) which sought global assurances from governments to reduce carbon emissions (Dunn, 2002). The 2000 European Climate Change Programme, which under its framework has presented pathways to achieve a 60% reduction in emissions for all modes of transport by 2050 (EC, 2003c). In terms of UK commitments, the government under its 2000 Climate Change Programme has obligated the economy to reductions in GHG emissions through mechanisms that includes; market regulations, subsidies, voluntary programmes and taxation.

While, the adoption of the Climate Change Act 2008, establishes a framework to reducing emissions by 80% relative to its 1990 levels by 2050 (HMSO, 2008). To achieve this level of reduction the 5.2 million SMEs (Rhodes, 2015) will potentially need to assist, if the government wishes not to struggle with achieving future targets. The difficulty was evident from the UK Energy Review (2006), in which the government struggled to make its 20% reduction in emissions target and SMEs were not mentioned (Bradford & Fraser, 2008).

2.5. Environmental impacts and SMEs

A review of the literature established that available quantitative data particular to the environmental impacts from SMEs is sparse and rarely reported (Berners-Lee *et. al.*, 2011; Kaenzig *et. al.*, 2011). A consensus however, exists among researchers that SMEs, even though they are individually small, because of the large numbers, do have a collective significant impact on the environment (Wilson, Williams & Kemp, 2012, Mir & Feitelson, 2007). That impact is estimated at being higher than larger businesses and households (Walker, Redmond & Giles, 2010a). The focus on

large businesses and their environmental impacts therefore, although understandable has been potentially misdirected.

In the UK, the Environment Agency (EA) calculated that SMEs are responsible for about 60% of commercial waste; as much as 80% of environmental incidents (Cassells & Lewis, 2011; Williamson *et al.*, 2006; Fairman & Yapp, 2005; Hillary, 2000) and 70% of industrial pollution (Hillary, 1995). Although many SMEs may attempt to exempt themselves from action due to their size (Tilley, 1999a) at an individual level, collectively their contribution to positively improving their environmental impacts is potentially significant (Tilley, 1999b; Hillary, 2004).

The reasons attributed to the significant environmental impacts by SMEs, are not only their numbers but also their industrial sector and the lack of operation techniques (Beckerman, 1996; Hobbs, 2000); thereby contributing to climate change and resource depletion from the practices they adopt. Environmental issues are generally associated with manufacturing and processing than with the service sector (Kolk, Walhain, & van de Wateringen, 2001). One reason for this association is the belief that this sector is environmentally friendly (Alcántara & Padilla, 2009) although there is insufficient research in this area to confirm that. However, with 80% of UK employees occupied within the service sector (BIS, 2013); and growing, responsibility towards the environment generally amongst SMEs is expected (Málovics, Csigéné & Kraus, 2008).

2.6. Environmental activities, programmes and SMEs

Empirical studies show that larger businesses adopt a proactive strategic approach and SMEs a reactive approach to environmental activities (Bianchi & Noci, 1998). The larger businesses activities are characterised by environmental programmes that anticipate external pressures and environmental changes are integrated into the business strategy, and are managed, resourced and has the commitment from managers, thereby aligned to a proactive environmental strategy (Bianchi & Noci, 1998).

SMEs activities are featured as aimed at compliance with external requests, resource compromised (Bianchi & Noci, 1998) and by definition reactive or *ad hoc*, as they lacked continuity (Millard, 2011) and result in *one-off*, piecemeal changes promoted and fostered by business support organisations (Stone, 2006a) and aligned to a reactive environmental strategy. As opposed to a programme of continuous improvement (Millard, 2011) fully integrated into the business with management support. While, Hillary (2000) reported that SMEs were ignorant of environmental impacts, lacked the tools to assist in tackling environmental issues and were resistant to action because of the resources needed.

Subsequently, environmental activities undertaken by SMEs to improve their environmental performance have lagged behind larger businesses (Hillary, 2000; Masurel, 2007). Although SMEs reported the environment was for them an important issue, however, in comparison with larger businesses they were less likely to emplace activities that would improve their environmental performance (Shaper, 2002; Crocker, 2012). The inaction of SMEs towards environmental matters can be seen from their reluctance to implement measures that would assist in reducing environmental impacts. SMEs surveys by NetRegs (2009a) for businesses in England found only 18% had assessed the impact of their operations on the environment and only 10% had made an employee responsible for environmental matters.

There appears however, to be a shift in attitude among SMEs, with a growing sense of responsibility evident in the literature (Málovics, Csigéné & Kraus, 2008; Revell, Stokes & Chen, 2010). However, still only a minority of SMEs are engaged in environmental activities with 39% engaged in energy efficiency measures and 30% altering products and services to become more environmentally friendly (FSB, 2007).

2.7. Accounting for environmental impacts and SMEs

In relation to sustainability and SMEs few standards for measuring economic and social impacts are evident. However, accounting methods and tools to measure environmental impacts are available and of interest in relation to their strategic relevance to the long-term improvement of sustainability in SMEs. A review of the main methods used to assess the impacts most notably for the service industries have included; use of the Greenhouse Gas Protocol (GHG Protocol); PAS 2050 and the ISO 14000 series of standards which specifies tools and requirements to manage environmental responsibilities and Defra/DECC guidances (IEMA, 2010). Each of these methods and tools has benefits and shortcomings.

The use of environmental tools for instance EMSs by SMEs assists them with addressing and reducing their environmental impacts (Ilomaki & Melanen, 2001; Burke & Gaughran, 2007). However, only a '*minuscule*' number of companies (Hillary, 2000; Walker, Redmond & Giles, 2010b) apply current EMS tools. In addition, tools that use databases lack transparency, are narrow and single issue focused (Weidmann & Minx, 2007; Wrigley, 2008; Heidrich & Tiwary, 2013), lack maturity (Moss *et. al.*, 2008; Wright, Kemp & Williams, 2011), lack consistencey (Padgett, *et. al.*, 2008; Kenny & Gray, 2009) and are transient (Moss, *et. al.*, 2008). While hybrid models, incorporating economic input-output parameters with process based LCAs (EIO-LCA) from Rosenblum, Horvath & Hendrickson (2000) and Berners-Lee *et. al.*, (2011); show the depth and quality of data being compromised by high levels of aggregation (Shrake, Landis & Bilec 2011). Accordingly, the research shows that tools presented to SMEs to reduce their environmental impacts are problematic.

A method that advocates transparency, is not narrow, is relatively mature, not transient, having been around in the USA since the 1960s is life cycle assessment (LCA) (Boustead, 1996). LCA is seen as a useful tool for determining significant environmental impacts and for larger businesses, reportedly assisting them with addressing and reducing their impacts (Frankl & Rubik, 1999) however; they are considered too resource intensive for SMEs. This may be a factor as to why full quantitative *cradle to grave* assessments are not used by SMEs. However, for simplified versions, their capacity, as a useful and suitable technique is unknown because few researchers have applied them within the context of SMEs (Junnala, 2006a). In taking into consideration all the aforementioned evidence, an empirical pilot study was conducted to explore current levels of, and approaches to, environmental activities.

2.8. Pilot study

A pilot study was undertaken to explore the current levels of, and approaches to, environmental activities amongst SMEs within the Bath and North East Somerset (B&NES) unitary authority during the period 2009-2010.

2.8.1. Background to pilot study

To explore environmental activities within SMEs, determining what an environmental activity entails, needs clarification. Defining and categorising environmental activity with respect of businesses amongst researchers is not consistent. Peattie & Ringler (1994) proposed environmental activities separated into *hardware* and *software* activities. The former referring to activities that are linked to technologies developed to reduce environmental impacts; the latter, with organisational activities notably environmental audits and policies. However, Gonzalez-Benito (2005) proffered categorising environmental actions into the following activities: communicational; product or process related operational; and organisational and planning. Although environmental activities are categorised differently within the literature they are unified in that any activities undertaken need to be identified as improving environmental performance.

The systems of categorisation suggested by the aforementioned researchers were not considered appropriate for SMEs. The operational and procedural structures consistent within a SME are not as acutely defined therefore the activities adopted by these categorisations would not be evident. Ramus' (2000) definition of an environmental activity as "*action that will improve environmental performances of company operations, products and services*" was however, considered apt for SMEs because it could accommodate less complex environmental activities. To explore the type and range of environmental activities, questions to the owner-managers were on energy, waste, raw materials, emissions, transport, their environmental practices and the action or measures they are taking to improve their environmental performance.

To explore the levels of, and approaches to environmental activities within the SME, a framework was needed to classify the different levels of activity that could be potentially found within a business. Tilley (1999b) reviews a number of environmental strategies with their typologies, developed by researchers that a business may go through to become more environmentally aware and presents her own from their underlying themes. Although each of the classification strategies had benefits and drawbacks, they were considered inappropriate in this instance. Some of the classification strategies were derived from corporate businesses, based upon the assumption that a '*small-sized*' version of a corporate framework would be suitable; others were couched within the context of ecological and environmental philosophy and the remainder a mixture of both derivations.

Subsequently, to explore levels of, and approaches to, environmental activities in which it could be determined from the activities undertaken by the SMEs whether they were integrated approaches, a classification by Palmer (2000) was used (see Figure 2.1.). This approach was used because it was developed specifically for use with small businesses and had the ability to ascertain the status of environmental activity from the involvement of personnel that could be indicative of an environmental strategy adopted by the SME.

2.8.2. Approach

Twenty-two SMEs employing fewer than 250 employees located in the B&NES region were questioned. The SMEs were selected because of their accessibility and proximity. This mode of data collection, convenience sampling was considered appropriate at this stage of the study because it can be used in pilot studies to obtain data trends when probability sampling is not apposite (Denscombe, 2007) (see Chapter 3, Table 3.10: p.57). A face-to-face semi-structured questionnaire containing both open and closed questions was administered personally to owners-managers.

Owner-managers for the purposes of this survey held a job within the business and had controlling ownership either alone, with family members or with a few partners. The interviews were conducted on-site and *face-to-face*. This *face-to-face* or personal approach took more effort and time (Aragon-Correa, *et. al.*, 2008). However, it was the preferred option because it confirmed the identity of the respondents; ascertained their comprehension of the questions being asked and ensured replies. The approach served to counter SME studies where results were inconclusive owing to low rates of responses (Merritt, 1998; Aragon-Correa, *et. al.*, 2008) and enabled industrial contacts to be established for additional research that was identified, and site processes to be observed.

The classification by Palmer (2000) detailed levels of activities conducted by SMEs into inactive, active, managed and standard (See Figure 2.1). The environmental activities undertaken by the SMEs were classified in accordance with the framework developed by Palmer (2000).

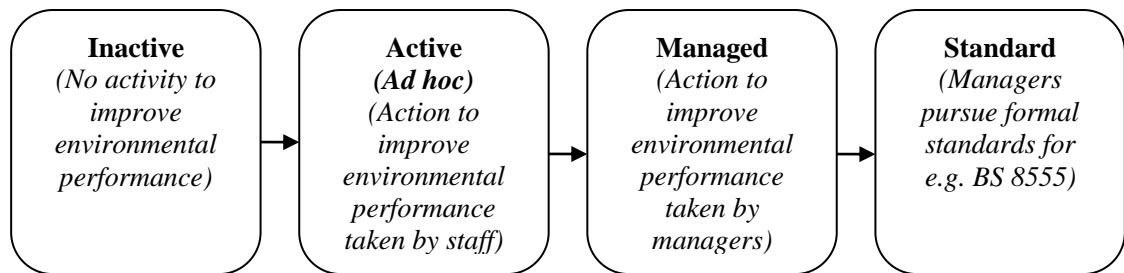


Figure 2.1: Classification of environmental activity levels for SMEs (Palmer, 2000)

The mode selected to survey the SMEs influenced the approach used to analyse the collected data. An analytical rather than statistical logic was therefore, used with interpretation of findings presented within the context of the discussion.

2.9. Results and discussion

To provide a context for the level of environmental activity amongst the SMEs it is necessary to discuss the business profile of those surveyed. First, a breakdown of the 22 SMEs surveyed using size or headcount as outlined by the European Commission (2003b) was used to categorise the businesses. Then the dominant sectors as determined by the UK Standard Industrial Classification (UK SIC, 2007) were identified (See Table 2.4 and Figure 2.2).

The majority of businesses in the survey were classified as a micro business, having fewer than 10 employees. In the UK for the year 2009, 96% of businesses were classified as micro, 3% as small, and 1% as medium (BIS, 2010a). The surveyed population although had a higher percentage of small businesses however; they reflected the dominance of the micro businesses within the UK population. Subsequently, any findings from the SMEs can potentially be seen as an indicator to trends within the UK and not Bath and North East Somerset (B&NES) unitary authority specific.

Table 2.4: Summary of the demographics from surveyed SMEs

Size and category of business	Total no. of businesses	Percentage of businesses
Micro < 10	16	~73
Small < 50	5	~23
Medium < 250	1	~4
Total no:	22	100

2.9.1. Profile of the surveyed SMEs

The business profile of the surveyed SMEs was established by considering their industrial division; gender, age and the type of premises from which the businesses operated, which were analysed and compared to the SW regional and UK national parameters to determine any trends, similarities, or

differences. Figure 2.2 shows the percentage of each SME surveyed in relation to their industrial division and standard industrial code (SIC). The three main sectors were manufacturing (~ 23%), accommodation and food services (~ 18%), wholesale and retail (~ 14%). The diversity and range of businesses reinforced the heterogeneous nature of SMEs within this small survey. The dominance of the service sector is evident with ~77% of the businesses surveyed reflecting its ascendancy within the UK. In terms of B&NES the industrial divisions broken down by sector is dominated by business services (45%), other services (13%), and construction (10%) (SWO, 2008).

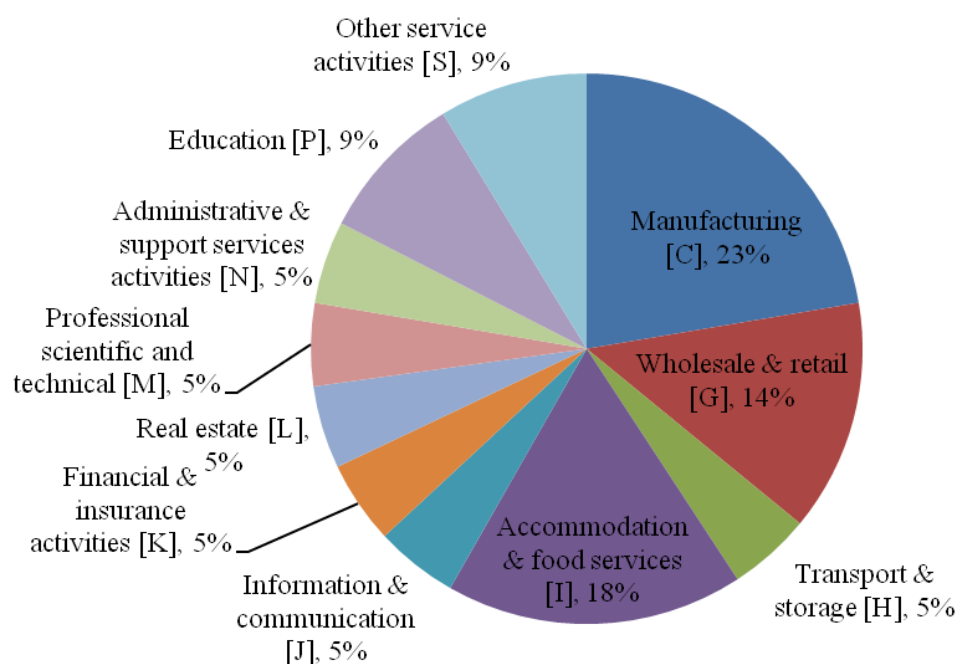


Figure 2.2: Surveyed SMEs and their standard industrial divisions and codes (UK SIC, 2007)

Table 2.5 shows the ownership and age profile of the surveyed SMEs compared to regional and national parameters.

Table 2.5: Profile of the surveyed SMEs compared to regional and national parameters

Profile parameters	Criteria	Pilot study (%)	Regional (SW) (%)	National (England & Wales) (%)
Ownership	Male	59	61	66
	Female	41	39	34
Age (years)	< 45	55	38	42
	≥ 45	45	62	58

Source: SWO, 2008

The percentage of owner-managers in the surveyed SMEs who were female was 41% and male 59%. The female involvement with SMEs in this region is higher than the England and Wales average of 34%, but only slightly higher than the SW figure of 39% (SWO, 2008). In terms of the B&NES region, female involvement in SMEs is quoted at 40%, which is reflected in those surveyed (SWO, 2008).

The age categorisation of SMEs owner-managers within the businesses surveyed shows 55% below the age of 45 and 45% over the age of 45. In the SW region, 38% are classified below the age of 45 and 62% as over the age of 45 (SWO, 2008). The surveyed businesses had a higher percentage of young owner-managers. In the SW, owners of SMEs are older than the England and Wales average where 62% are classified as over the age of 45 as opposed to 58% (SWO, 2008). The reason has been attributed to the SW having an older than average population and lifestyle choices where owner-managers over the age of 45 tended to be located in rural areas (SWO, 2008). In the surveyed businesses, the higher percentage of young SME owner-managers can be attributed to the non-rural bias. The surveyed businesses afford comparisons with the district/county authorities of Swindon, Bristol and Plymouth with the youngest SMEs owners accounting for 48%, 47% and 46% respectively (SWO, 2008). In relation to the type of premises from which the business operated; 68% worked from rented or leased premises; 27% owned their premises and 5% were home based, of which the mean average age of a business was ~10 years.

This outline of the profile for the surveyed SMEs is important because it places the businesses surveyed within the context of local, regional, and national parameters, which can influence the levels of, and approach to environmental activities. For instance, the literature shows that the manufacturing sectors are environmentally more aware than other sectors because of their environmental impacts (Hillary, 2000) and rental or leased premises may have perceived barriers to the implementation of environmental initiatives (CRiBE, 2009) and that gender and age of the owner-managers influences environmental activities (Stern & Dietz, 1994; Steel, 1996; Casey & Scott, 2006).

The key findings from the surveyed SMEs were as follows:

- Nearly four-fifths, ~77% of businesses was involved in the service sector
- Males represented 59% of the businesses surveyed
- 55% of the owner-managers surveyed were below the age of 45
- 68% of owner-managers operated their businesses from rented or leased premises.

In the first instance, the trend based on a profile of the key findings would indicate the surveyed businesses would be considered as inactive because from the evidence, males below the age of 45 and operating from leased or rented premises are presented as predominantly taking no activities to improve environmental performance.

2.9.2. Types of environmental activities

Three types of environmental activities were undertaken by the surveyed SMEs to improve their environmental performance. The main measures consisted of energy, waste, and water initiatives.

The implementation of energy efficiency measures, which comprised of an array of initiatives ranging from lighting, insulation and heating controls were implemented by 77% of the businesses, of which 63% were lamp modifications. Waste management initiatives especially recycling was undertaken by 64% of businesses in the survey. The water reduction initiatives, which included measures that ranged from the use of spray taps, *water hippos*, dual flush lavatories, water meters and instantaneous hot water heaters were being used in 50% of the surveyed SMEs. However, of these water initiatives undertaken by the resident businesses 36%, were low cost water saving devices most notably *water hippos*. In relation to the established literature, the surveyed SMEs action to improve environmental performance was high especially the energy and water reduction initiatives (NetRegs, 2002; 2005a,b; 2007a,b; 2009a,b & EA, 2003). A contributing factor to these high values can be attributed to funded initiatives from the Energy Savings Trust (EST) and Envision that had been promoted by the funding stakeholder, the FSB.

2.9.3. Level of and approach to environmental activity

The surveyed SMEs in accordance with Palmer's classification showed that 9% of the businesses took no direct activities to improve environmental performance and were considered inactive. Actions to improve environmental performance were undertaken by 68% of the surveyed SMEs and although considered active, the actions undertaken by employees were *ad hoc*, of which three underlying characteristics were evident. Individual employees although took action to improve environmental performance, there was no continuous or regular monitoring system *in situ* and the action was a '*low-hanging fruit*' to obtain a perceived '*quick-win*' (Collins, Roper & Lawrence, 2010). Action to improve environmental performance taken by managers was evident in 23% of SMEs surveyed and included for example the installation of instantaneous hot water heaters. None of the SMEs surveyed were at a standard level and managers had not implemented a formal systematic integrated programme to improve environmental performance for instance, an environmental management system (EMS) or equivalent. There was a lack of measuring and monitoring amongst the surveyed SMEs, which was indicated by none of the businesses pursuing or adopting a formal procedure to improve environmental performance.

The findings slightly differ from those presented in the literature on two aspects. The first is that the majority of SMEs presented in the literature were classified within the inactive stage and as such took no action to improve environmental performance (Palmer, 2000). Moreover, managed and standard status levels in the literature were rare and seldom visible (Palmer, 2000). The differences between this study and the established literature can be attributed to the influence of young female owner-managers who are deemed more environmental receptive than young male owners-managers (Casey & Scott, 2006). In addition, the predominance of older and more established SMEs in the survey may influence the adoption of environmental initiatives. The mean

business age was ~10 years and, owner-managers maybe more likely to look at additional ways of improving their '*bottom-line*' and one way is to consider the environmental perspective.

The pilot study however, confirmed studies that the majority of SMEs had not progressed further than an active stage and employees were engaged in mere *ad hoc* actions, and a minority undertook managed and standard level activities, which involved management commitment and additional resources. The majority of surveyed SMEs were therefore, reactive in their approach to environmental activities. This is potentially important because a lack of commitment and investment prevents environmental performance from being planned, implemented and measured and by implication sustained.

The surveyed SMEs responded that their level of environmental activity was *driven* by the potential to reduce costs, (~32%); to reduce carbon emissions (~ 27%) and to comply with legislation to avoid the risk of prosecution, fines, and penalties, (~23%). The only driver that received no validation from the SMEs was to, '*motivate, attract, or retain staff*'. The established literature as presented by Gadenne, Kennedy & McKeiver (2009); Wilson, William & Kemp (2012) and the SME-environment surveys for the years 2002 to 2009 (NetRegs, 2002; 2005a,b; 2007a,b; 2009a,b & EA, 2003) showed compliance with legislation is featured as a main driver for SMEs to implement environmental measures. The potential reasons for the divergence from the literature can be attributed to the size of the businesses; the surveyed establishments containing less polluting industrial sectors and therefore, less need for stringent regulations.

The reduction of costs was the prime driver for implementing environmental measures within the surveyed businesses. The results are based upon the SMEs perceived benefits of implementing an environmental measure. The stated benefits in terms of cost were not evident. The response from the SMEs reaction may reflect the influence of environmental publicity; from schemes such as IYRE, which was being promoted within the area as helping SMEs to reduce their environmental impacts, while increasing their profits. The Palmer (2000) classification was additionally used to express the drivers that cause a SME to take action to improve their environmental performance. By classifying the drivers in terms of an environmental activity level or status, it would enable the action to improve environmental performance to be seen in relation to the different status groups (See Figure 2.3).

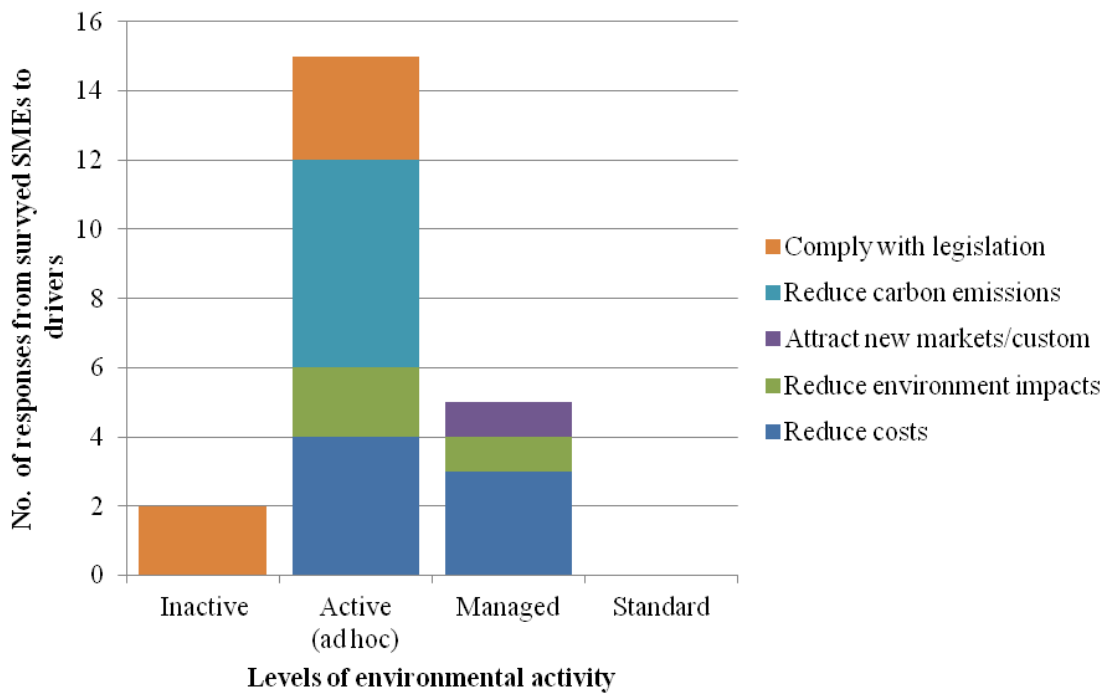


Figure 2.3: Levels of environmental activity and drivers

The inactive group would only been driven to adopt environmental measures if they were legally obliged; the *ad hoc* group took action primarily for environmental reasons to reduce their carbon emissions and the managed group took action for potential economic benefits, to reduce costs. Different drivers influenced the levels or the status of environmental activity within the business, which highlights the diversity and intrinsic complexities of SMEs in terms to getting improvements in environmental performance.

2.9.4. Limitations of approach

The pilot study had a number of limitations and shortcomings that resulted from external factors that could not be controlled. A short lead-in and limited time frame; produced a small SME survey and an analytical rather than statistical logic to the interpretation of the findings. This approach limits generalisation and conjecture about the population as a whole. However, in spite of these limitations, the study builds upon existing empirical literature by showing the dominance of service industries in the southwest and the need for sustained action to improve environmental performance.

2.10. Concluding remarks

The findings for the level of environmental activities amongst the surveyed SMEs can be summarised as follows:

- SMEs are predominately service sector businesses

- 9% of owner-managers had not implemented one practical environmental measure to improve environmental performance
- 68% were active but *ad hoc* in their approach with improvements in environmental performance, characterised by being left to the interests of and/or taken by individual members of staff
- No SME was managing their environmental performance formally and using ‘tools’
- There is a paucity of environmental baseline data therefore, by implication no formal management of impacts
- 77% of SMEs had not progressed beyond the active stage where employees were engaged in mere *ad hoc* actions to improve environmental performance
- SMEs adopted a reactive position towards the environment as opposed to a pro-active strategic stance

The findings showed that the three drivers that influenced the levels of environmental activities were the potential to reduce costs, to reduce carbon emissions and the compliance with legislation to avoid fines and penalties.

In terms of potential reduction in costs, generally easily achievable savings for waste and energy has been realised and applied by the SMEs (Sitarz, 2008, Goodall, 2009). Accordingly, diminishing returns therefore inhibits further savings from government-funded programmes. The government funded programmes focus on the *quick-wins*; for instance, the recycling of waste and the replacement of incandescent light bulbs with more energy efficient fluorescent or halide bulbs. However, the problem remains; that when the programme is completed there is no follow through. Subsequently, to enable SMEs to carry on obtaining advantages from environmental activities and reduce their emissions further a new approach needs to be considered that results in sustained improvements.

The secondary evidence from the pilot study highlighted the dominance of the service sector and reinforced that SMEs still took limited sustained measures to reduce environmental impacts from activities. Environmental responsibility, it has been suggested is not realised because impacts are not identified and measured (Bowyer *et al.*, 2005). To attain greater accountability from SMEs, the lack of measuring within the sector caused the contemplation of the type of environmental accounting that could be integrated to become part the business’ overall environmental management strategy.

The literature shows there is a lack of research on the value of life cycle approaches within the context of SMEs and service industries (Junnala, 2006a). Accordingly, there is a research need to consider the environmental impacts of SMEs from the service industries; as there is general

agreement that the service sector is environmentally friendly (Junnila, 2006b; Alcántara & Padilla, 2009; Gaidajis, 2011). However, with over 30% of the workforce in industrial nations connected to the service economy (Lehmann & Hietanen, 2009; Gaidajis, 2011) and the continued growth of this sector, their environmental impacts need to be addressed as they may not be benign.

2.11. Life cycle based approaches

A life cycle assessment (LCA) is a tool that evaluates the environmental impacts of a service or product, from its inception to its demise, depending on its system boundary (Todd & Curran, 1999; Curran, 2006). The research in this area has focused upon larger organisations and their products (Seidel, *et. al.*, 2009) resulting in a paucity of research that explores the value of life cycle approaches for use by SMEs. LCA approaches have evolved immeasurably since the 1960s. New approaches to modelling have been developed. Subsequently, this continued evolution of LCA has resulted in its increasing relevance and popularity within the discipline of sustainability and the measuring of environmental impacts (Zamagni, 2012); in spite of its well-documented disadvantages (Seidel, *et. al.*, 2009; Weidmann & Minx, 2007).

The preceding discussion shows SMEs need to take action and improve environmental performance however, their limited resources and differences from larger businesses places explicit requirements on any life cycle assessment approach (Cagliano, Blackmon & Voss, 2001; McKeiver & Gadenne, 2005). A full *cradle to grave* life cycle is the ideal option however; discretion is required to determine what parts of the service can be included or omitted. The flexibility of LCA with no approach dominating therefore, enables this study. A RLCAA in this research therefore, refers to a simplified and less resource intensive life cycle based approach; used to assess the environmental aspects of services, that measures the wider environmental impact detail and depending upon the system from the inception of the service to its demise. The approaches used can be quantitative, semi-quantitative or qualitative where parameters are primarily determined from readily available data from the SME, databases or literature.

The importance of system boundaries and a framework with guidelines to assist in addressing the environmental aspects and impacts of a service is emphasised in RLCAAs. Accordingly, RLCAAs are guided by the four generic phases and the iterative process as outlined in the ISO 14040, 2006a and 14044, 2006b (see Figure 2.4):

In a RLCAA the goal and scope; establishes the system boundaries; the extent and objectives of the assessment. The inventory analysis focuses upon gathering data while, the third phase; impact assessment, involves evaluating the data in relation to the contribution the aspects make to selected environmental impact categories for instance, climate change. The final phase consists of the

interpretation of results, which involves organising the findings from the assessment into outcomes and drawing conclusions.

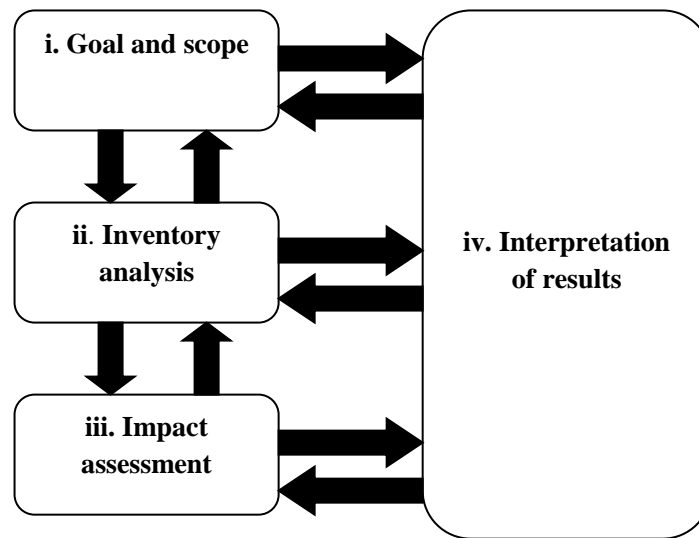


Figure 2.4: Four phases of a LCA (source: adapted from Curran, 1996: ISO, 2006a)

2.12. Summary

There are International, European and National commitments undertaken by the UK government to assist in the reduction of emissions. To assist with achieving the targets SMEs will need to play a role. SMEs are notoriously difficult to engage with improving their environmental performance and there is a perception because of their size their environmental impacts are limited. However, cumulatively their environmental impacts are potentially substantial.. The literature and confirmation findings in the pilot study demonstrated that the levels of environmental activity among SMEs was limited and the majority, 77%, and not proceeded beyond the active level where actions to improve environmental performance were *ad hoc* and taken by individual employees.

The managed and standard levels where management and commitment were involved in improving environmental performance was undertaken by 23% of SMEs. In the literature, environmental activities among SMEs were highlighted as being '*one-off*' and aligned to a reactive environmental strategy, as opposed to a proactive strategy which affords the integration and adoption of broader environmental principles into the business (Stone, 2006a, 2006b). The pilot study confirms the literature findings; accordingly, a more proactive strategy with managed activity levels is needed by SMEs to improve environmental performance.

The tools available to SMEs that would assist with integrating environmental improvements into the business, promote continuous improvement, create greater awareness about environmental issues and obtain staff participation and management commitment are limited. The tools currently accessible have not been successful as indicated by their limited uptake or compromised by

technical, data aggregation and transparency concerns. Subsequently, there is a need to consider the frameworks of tools that have been ignored because they have been deemed too resource intensive for use by SMEs even though no research has been undertaken with this regard. Accordingly, there is a need to explore the value of life cycle based approaches for use by service industry SMEs. The review of the literature coupled with the pilot study has revealed four gaps in the evidence relating to the potential of SMEs to improve environmental performance.

i. Approaches used currently to address environmental aspects and environmental impacts of a service are limited, and used by a *minuscule* of businesses. The other approaches and tools are carbon emissions focused thereby providing a restricted view on impacts and ignoring the broader environmental issues

ii. Evidence on the type of data that can be provided by service industries to report GHG emissions are lacking and consequently the extent of emissions produced by these SMEs is unknown

iii. Verification from service industries as to the environmental impacts caused by conducting their specific services is varied therefore; additional evidence is needed to determine the effect of these businesses on the environment

iv. Data from the viewpoint of operational employees from service industry SMEs is lacking in terms of the measuring, managing and reporting of emissions therefore, more evidence is needed to establish their views and opinions in light of undertaking a proactive environmental strategy to assess environmental aspects and, in the event of potential reporting obligations

To address the aforementioned gaps, data will be gathered from UK SMEs, employees and owner-managers associated and employed in service industries.

Chapter 3

Research Approaches

The objectives of the research and its interdisciplinary nature influenced the techniques and strategies adopted in the design of the study. The design enabled nuances and subtleties within the SME sector to be addressed which can be omitted from a purely quantitative study (Hill & Wright, 2001). In this chapter, therefore, the choices of approaches are outlined; processes used to collect the data are described and the techniques, qualitative, quantitative and semi-quantitative used in the analysis of data are presented.

3.1. Choice of techniques and approaches

A number of lateral and critical techniques were initially considered to conduct the research. Tools, for instance that assists with generating, harvesting and treating ideas and those connected with problem-solving, analysis and forecasting for example, TRIZ (theory of inventive problem solving) were explored. These techniques and approaches were not appropriate in respect of engaging with the population of interest; SME employees and owner-managers in which relevance to their business, familiarity and time constraints prevailed. Moreover, the choice of techniques and approaches adopted in the light of the aim and objectives enabled them to be addressed, and achieved effectively, using approaches that are more customary.

A quantitative online survey was initiated during September 2011. The online survey was used because fixed data indicators (Bryman 2012), that can be used as values in GHG conversion applications was needed, and this proved the most suitable vehicle for a ICT conversant target population. The data to be collected needed to be accurate and this approach is noted for obtaining data accuracy to knowledge questions (Greenlaw & Brown-Welty, 2009, Fricker *et al.*, 2005). In addition, this mode of data collection as measured against equivalent paper-based versions was used because it has higher completion rates than paper-based questionnaires; they generate information that is more complete with fewer missing responses (Kaplowitz, Hadlock & Levine, 2004; Densombe, 2006; Denscombe, 2008; Olsen, 2009) while eliminating the possibility of interviewer effects (Braunsberger, Wybenga, & Gates, 2007). This mode of data collection was suitable for this sector because of these strengths and was the preferred approach when contrasted with its comparative paper-based option.

The tool used on the environmental data from the online surveys was the online UK Defra/DECC application. This tool was used because of its accessibility to the target population; it is the tool recommended by the UK government for use by SMEs and, it enables the emission releasing

activities to be organised into scopes (see Chapter 3, Table 3.8: p.47), which is considered a conversant approach amongst businesses (DEFRA, 2013a).

To explore, establish and uncover the views, beliefs and opinions of SME employees and have the potential to understand the underlying reasons for them, from a grass roots '*bottom-up*' perspective, a qualitative approach was appropriate (Strauss & Corbin 1990; Warren 2002). A roundtable discussion was therefore, conducted in January 2012.

Researchers, to investigate SMEs have used focus groups to explore, establish, and gain insight into small business practices and attitudes (Hutt, 1979; Berry & Ladkin, 1997; Vyakarnam *et al.*, 1997; Heneman, Tansky & Camp, 2000; Vernon *et al.*, 2003) and to complement quantitative studies (Newby, Watson & Woodliffe, 2003). Focus groups were not an option in this instance because the approach has to reach '*saturation point*' and resources were limited. A roundtable discussion comparable to a focus group was used for the following reasons:

- Format enables '*what*', '*where*' '*why*' and '*how*' questions to be posited thereby obtaining different information from surveys and one-to-one interviews (Newby, Watson & Woodliffe, 2003)
- Engenders openness by shifting the power balance between the researcher and the researched; the former is in the minority therefore, the participants among their peer group are more willing to discuss topics in their own language than in one-to-one interviews (Blackburn & Stokes, 2000) and
- Serves as an effective stand alone approach

The life cycle based approaches, a semi-quantitative technique, using a matrix tool and applying a pragmatic approach and the quantitative technique, using the commercial tool, SIMAPRO, and a magnitude approach were trialled on data collected from three case studies. The approaches were developed and applied because they were theoretically, technically and practically different and the tools can be used retrospectively; thereby enabling environmental aspects to be assessed and findings compared and contrasted to determine suitability for service industry SMEs (see Figure 3.1. for a diagrammatic overview of the research approach).

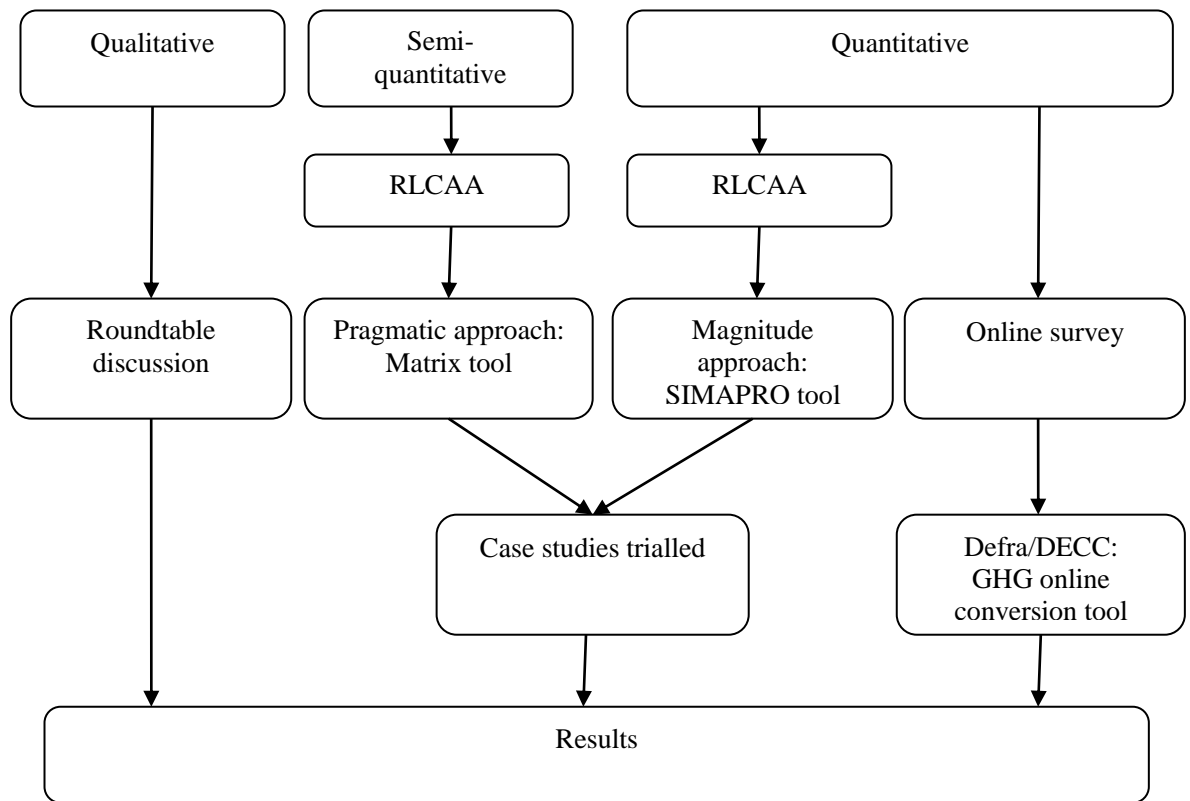


Figure 3.1: Diagrammatic overview of the research approach

3.2. Data collection approach

SMEs are notoriously difficult to engage (Blackburn & Stokes, 2000; Hillary, 2000; Millard, 2011) therefore, getting them to participate in the research and the differing levels of commitment needed resulted in utilising a number of data collection approaches to achieve the study objectives. For instance, participants were needed to take part in the online survey; a roundtable discussion, and as case study material, which entailed greater interaction over a prolonged period with the research study.

To address *Objective 1*; to identify the type of data available from service industry SMEs that can be used to report the amount of GHG emissions being produced; questions were developed that could be accommodated in an online survey. Data was collected from contacts that were on the University's approved supplier's database and provided by respondents on the following:

- Electricity consumption in kWh/annum
- Gas consumption in kWh/annum
- Transport information that consisted of predominately business and commuting travel per annum
- Weight and / or quantity of business waste per week

- General information about the business: total floor area, number of employees and FTE (full-time equivalents), type of service and responses to the reporting of carbon emissions
- Capital items information: type and numbers of equipment used by the business

To address *Objective II*; to establish the views and opinions of service industry employees from SMEs to measuring, managing and reporting GHG emissions, a roundtable discussion was undertaken; with seven participants employed in service industry SMEs.

Two digital audio tape recorders (Zoom H2) were used to record participant answers, questions, comments, and reaction with their permission. In addition, to the recording, 'field notes' were taken during the process by two assistant moderators. This approach was employed because it minimised note taking and made the discussion process the focus (Krueger, 1998b). In addition, the recording can be reviewed many times and the 'field notes' taken during the process was used to confirm recorded information when the participants responses were too faint to be understood (Krueger, 1998b).

To assess the environmental aspects, a number of SMEs needed to be recruited onto the study so that data could be collected; models defined and created to trial the RLCAAs. Nineteen SMEs were approached and three-service industry companies were used to test the two approaches.

3.2.1. Primary data: online survey

At this juncture it needs to be acknowledged that there is ambiguity and conflict amongst the research findings regarding the effectiveness online surveys. An approach for use with online surveys in terms of the strategies needed to increase responses to survey emails and the optimising of survey design to maximise unit response rates and data quality has not been established (Dillman, 2000; Schonlau, Ronald & Elliott, 2002; Sue & Ritter, 2012). The current research literature on unit response rates and data quality from online surveys is ambiguous. Some research studies show online surveys producing lower responses rates compared to mailed paper questionnaires, around 11% in some cases (Manfreda, *et al.*, 2008; Shih & Fan, 2008). Other studies however, show online surveys are either comparable or produce improved response rates when considered in relation to paper mail surveys (Kaplowitz, Hadlock & Levine, 2004; McCabe, 2004; Kiernan, *et al.*, 2005). In Greenlaw & Brown-Welty's study (2009) on professional employment, they reported a 52% unit response rate for online surveys as opposed to a 42% rate for the paper based mailed survey.

Research on the quality of data measured in relation to item response rate, between online and mail surveys are inconclusive (Shu, 2005). Borkan (2010) reported there are no effects on data quality between the two delivery modes. Others have reported online surveys produce data of improved

quality (Denscombe, 2006, 2008 & 2009). The findings of online studies however, appear to be dependent upon the target population, survey samples and administrative design (Truell, Bartlett & Alexander, 2002; Shin, Johnson & Rao, 2012).

Online surveys have been used however, within the field of business to collect data (Shu 2005) and is seen as a promising method of data collection (Greenlaw & Brown-Welty, 2009), although it is sensitive to the characteristics of the target population (Shu, 2005). The increase use of information and communication technology (ICT) in small business is now ubiquitous with only 5% of SMEs reporting that they do not use computers (McCann, 2010). An online survey therefore, was considered acceptable for data collection from SMEs because over 80% reported to having internet access and using email and online communications (McCann, 2010). Remaining mindful of the inconsistencies within the literature a survey framework was developed to ensure primary data was robustly collected (see Figure 3.2).

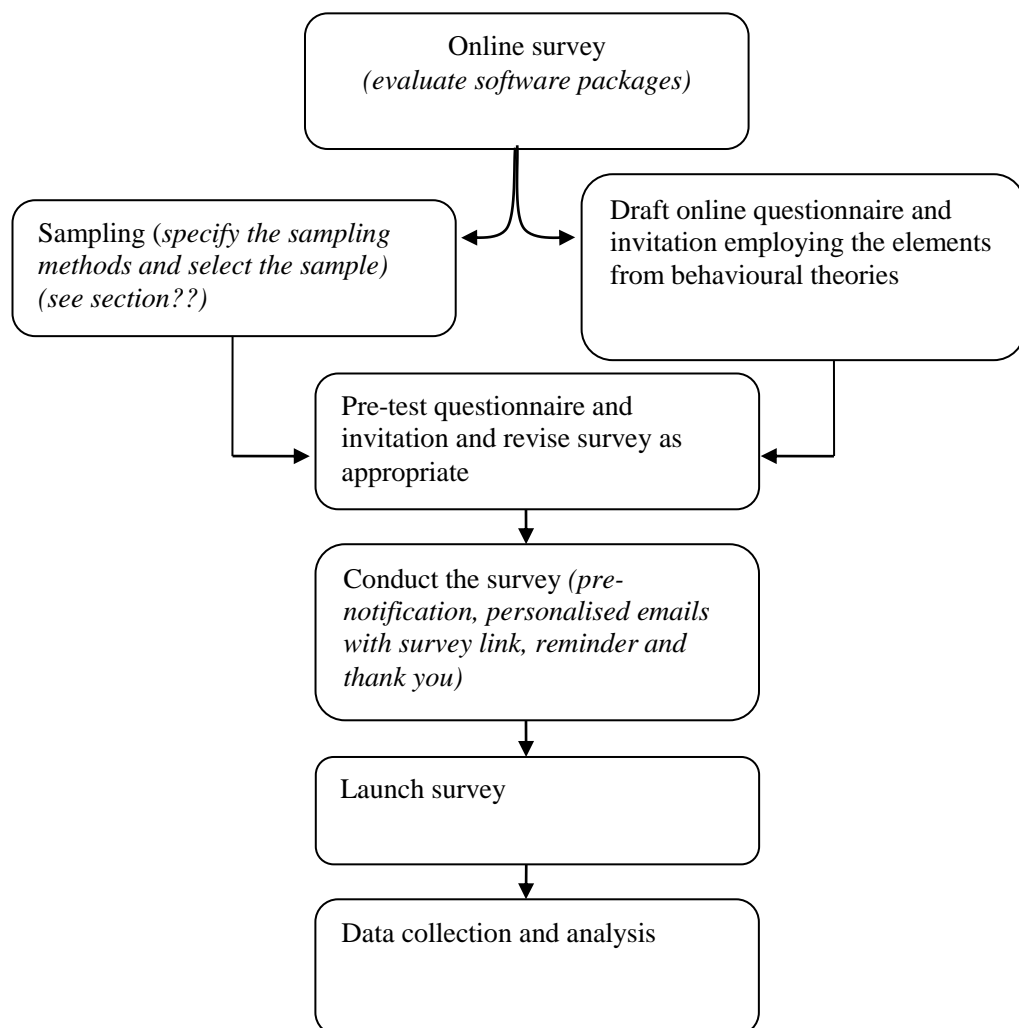


Figure 3.2: Survey framework outlining the processes undertaken to conduct an online survey (adapted from elements used by Dillman, 2000; Dillman *et. al.*, 2009 & Fowler, 1993)

A number of easy to use and accessible survey software packages were evaluated. A Google search in August 2011 showed the top three easily recognised online professional questionnaire surveys was SurveyMonkey, Zoomerang, and SurveyGizmo (Mora, 2011). The survey software in terms of comparisons had their own idiosyncrasies, disadvantages, and advantages. For instance, SurveyMonkey's basic versions allowed only 10 questions in each survey, SurveyGizmo did not provide specific sample templates and Zoomerang's data surveys expired after 10 days. The online survey package used and preferred therefore, needed to relate to the research parameters and the population of interest.

This research focussed upon service industry SMEs in the UK and in keeping with the research's ethos, the online paperless survey software chosen was from a locally based company in Gloucester. This survey software not only promoted the research's philosophy but also possessed the necessary features needed to conduct the study in terms of design, data collection, and reporting characteristics and data encryption facilities and price. In addition, it provided a notable distinction from the corporate packages that a heterogeneous sector would appreciate. A survey was created using the software that could be accessed by participants through a link in an email invitation.

3.2.1.1. Online survey emails

A number of strategies to increase responses to the survey emails have been proffered. Four main stages were discerned from the research literature (Schlegelmilch & Diamantopoulos, 1991; Diamantopoulos, Schlegelmilch & Webb, 1991; Dillman, West & Clark, 1994) that had been shown to be successful and were used in this study, which included the following.

- Pre-notification and personalised email informing the SMEs about the survey and inviting them to participate
- Personalised email containing the hyperlink to the survey
- An email reminder to complete the survey with the hyperlink to the survey and a
- Thank you email

To ensure respondents opened the survey and did not automatically delete the email; subject lines on survey viewing and responses were researched to maximise the response rates. In this instance, previous research had shown that the use of sponsorship by a University institution has a higher response rate than sponsorship by other organisations (Heberlein & Baumgartner, 1978; Fox, Crask & Kim, 1988). As a result, although additional sponsors as well as the University supported the research, the academic institution and emailing facilities were used in the strategy to increase response rates.

In terms of the email's subject line: requests for help have been shown to raise response rates (Mowen & Cialdini, 1980; Porter & Whitcombe, 2005) while the mention of the term survey in the subject line results in lower response rates (Porter & Whitcombe, 2007). Accordingly, requests for information from the SMEs and mentioning the University in the subject line were included in the pre-notification email.

The pre-notification email was sent to SMEs, which outlined the survey's purpose, emphasised its importance and the value of participation and informed the potential respondents when they would receive the survey (Van Selm & Jankowski, 2006; Sue & Ritter, 2012). This was undertaken to increase the response rate because the email primed the respondents for its arrival, established the legitimacy of the research and showed this is not spam because spammers do not notify (Sue & Ritter, 2012). The pre-notification email also served a number of additional purposes, which were as follows:

- Provided details that enabled the potential respondents to contact the researcher for further information
- Enabled the potential participants to withdraw from the study
- Confirmed if the email address was current thereby, any further communication would be reserved for SMEs who had '*live*' addresses
- Provided the information that enabled the database to be updated for ongoing research
- Validated that all potential participants are still employed at the SMEs of interest

Personalised emails were sent to named individuals. The SMEs privileged and unique position not only as a University supplier but also at being selected for this survey and the importance of their feedback was emphasised, because it had been demonstrated that these types of emails increase response rates (Porter & Whitcomb, 2003; Van Selm & Jankowski, 2006). The subject line, contained the name of the respondent and an email containing a hyperlink that logged the participant into the survey web site if clicked. To further increase, response rates and data quality, a number of strategies emphasised in the literature was used.

The strategies were borrowed from behavioural theory, couched within the terms level of engagement (Bandura, 2001) and self-perception (Laird, 2007). In terms of the former, the literature mentions that involvement and commitment to an organisation can promote participation (Bandura, 2001). The potential respondents are suppliers to the organisation, the University, who are on the list because of their environmental credentials. The suppliers' level of involvement and environmental predisposition takes advantage of this involvement as a motivator for them to participate.

The latter, self-perception theory, relies on the respondents viewing themselves as being helpful and kind (Laird, 2007). By requesting suppliers participate via the pre-notification email the offer is made for them to manifest these qualities and those that choose to identify with the labels ‘helpful’ and ‘kind’ will endeavour to respond to the survey. This is demonstrated in the following text:

‘I would be really grateful if you would consider participating in this survey, which will be arriving in your email inbox during the week starting Monday 19th September’.

The procedure in conducting the survey determines that the purpose of the survey needs to be explained and the approximate length of time it will take to be completed; in addition, to issues of confidentiality and anonymity. These aspects were undertaken in both the pre-notification email and the personalised email containing the hyperlink to the survey as appropriate and are illustrated in the following text:

‘A few days ago I sent an email notifying you that we were running an important online survey where we needed to gauge the views of our University service providers/suppliers on the reporting of carbon emissions and the feasibility of accurate data collection by SMEs for their energy, waste and transport.’

‘This short survey should take between 10-15 minutes to complete...’

‘...responses you provide will be completely confidential.’

The survey link was highlighted and the use of colour served to make it easier to find while the full URL enabled those respondents to copy and paste it into their browser window rather than clicking into the link (Couper, 2008). The use of these two response mechanisms made it easier for respondents to respond and access the survey,

‘To access the survey please click on the link below:

<http://www.smart-survey.co.uk/v.asp?i=40529nxset> ‘

The development of the survey design, procedures adopted, and decisions taken needs to be delineated. Delineation is needed because empirical evidence is lacking from which to draw definitive conclusions about optimal design and their employment (Sue & Ritter, 2012). In addition, the design is important to ensure that responses are maximised and to counteract potential biases such as:

- web respondents producing a higher '*don't know*' response rate (Heerwegh & Looseveldt, 2008)
- respondents differentiating less on rating scales and producing more item non-responses than face-to-face survey respondents (Heerwegh & Looseveldt, 2008) and
- to minimise '*break-off*' (Peytchev, 2009) which is increased where the respondent has to retrieve information.

3.2.1.2. Online survey framework

A framework for designing an effective online questionnaire has not been determined in the research literature. A framework was developed by using best practice, the general principles from conventional survey practice as described in the research literature (Dillman, 2000); but amended to accommodate recent advances in, and familiarity with surveys conducted online (Taylor, 2000; Deutskens *et al.*, 2004; Sue & Ritter 2012).

Accordingly, the elements of the *tailored (or total) design method* (TDM) for mail surveys (Dillman, 2000) and *total survey design* (TSD) (Fowler, 1993) were used and modified to improve response rates. The modifications were made in relation to the online mode of contact and target population because the implementation approaches that benefit mail surveys are noted as not translating directly to response rate benefits for online surveys (Couper, 2000).

A framework on the design principles pertinent to online surveys may seem rather excessive and unnecessary. The principles used to design and create a paper questionnaire can be helpful in producing an online version. Online surveys however, are distinctive and additional thought is needed when considering the layout, user and technical practicalities (Schonlau, Ronald & Elliott, 2002); especially as a lack of consensus exists as to what makes up a respondent responsive design.

The framework used to develop, design and deploy the online survey using survey software is presented in Figure 3.3. Time was allocated to develop and design the online survey because poor survey design can reduce the rate of the responses to the survey and result in biased answering triggered from visual elements of a questionnaire (Deutskens *et al.*, 2004).

Incorporated into the online survey, to increase responses material and non-material incentives were used. Research has shown that material and non-material incentives such as a summary of results and feedback increased the likelihood of the person responding and completing a survey (Kanuk & Berenson, 1975; Church, 1993); in some instances by 19% provided, they are relevant to the target population. (Göritz, 2006).

Incentives were used to increase response rates based on current survey methodology and social exchange theory (Emerson, 1976; Homans, 1958). The theory maintains that decisions to take action are evaluated in relation to costs and benefits (Dillman & Smyth, 2007; Fan & Yan, 2010). Respondents when offered an incentive will weigh the value of the incentive against their perceived cost in effort and time (Homans, 1958; Groves, Cialdini & Couper, 1992). The quality of the response is not affected by the incentives and to maximise response rate three options were offered that catered for material and non-materials morays. The incentives were as follows:

- Entry into a Free Draw ~ to win a three hour bespoke carbon/energy assessment commercially valued at £500
- Participation in a Focus Group
- Obtain some Feedback ~ on the results

The rationale for the incentives was that the offers were all relevant to the participants in terms of environmental interest. The free draw reflected the social exchange theory and although open to all participants used the lottery scheme incentive, which in the literature has proved significant in obtaining responses from long surveys (Deutskens, *et. al.*, 2004). In this instance, the incentive is evaluated by the respondents in terms of reimbursement for the effort and time spent to filling in the survey (Sue & Ritter, 2012; Deutskens, *et. al.*, 2004). While the other incentives work on degrees of involvement and catered for the respondent's pro-active and passive engagement in environmental issues.

3.2.1.3. Online survey design

In developing the survey, the layout, appearance and respondent friendly aspects needed to be considered and these are discussed in the next sections. This is important because it was necessary to not only mitigate potential low response rates but also encourage response quality (Grant, Teller & Teller, 2005).

One of the requirements in developing an online survey is to use a welcome screen to explain about the survey (Couper, 2008). A welcome screen was not used in this design because the targeted population had received a pre-notification email that outlined the research and survey. A '*welcome paragraph*' however, thanked the recipients for taking the time to fill in the survey and provided information needed to complete the survey. A guarantee that the information would be used for research purposes only and in a manner not to identify individual responses thereby assuring their privacy was provided.

The demographics of the target population influenced the formatting of the survey (Deutsken *et al.*, 2004). The survey was presented in a conventional paper questionnaire format, with instructions

and section headings where appropriate because plain surveys result in slightly higher rates of response than *'fancy'* surveys (Dillman *et al.*, 1998 cited in Schonlau, 2002; Deutsken *et al.*, 2004). This brings into focus survey length and the number of questions.

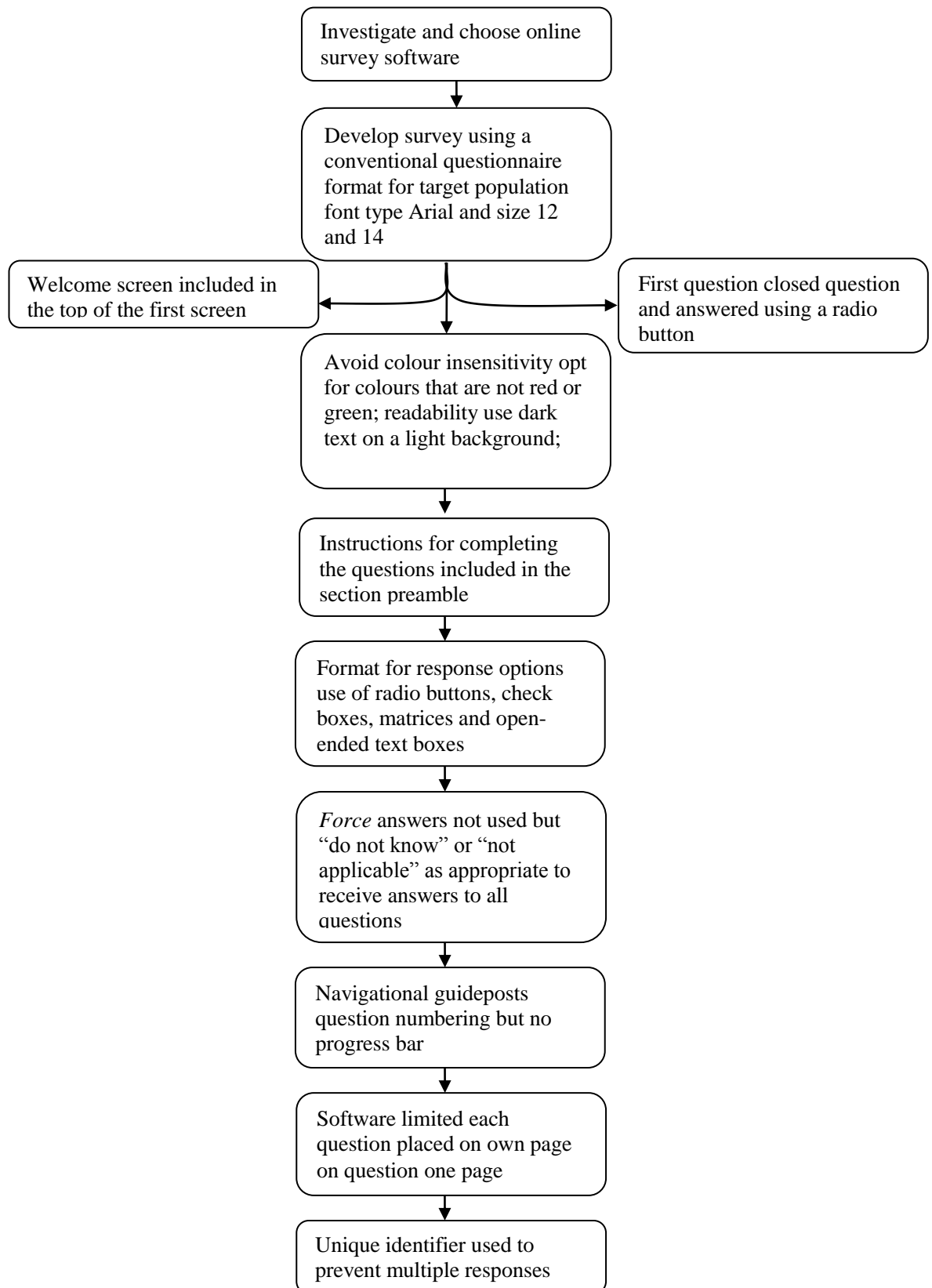


Figure 3.3: Framework used to develop, design and deploy the online survey using survey software (adapted from general principles outlined by Dillman 2000; Dillman & Smyth, 2007)

When the literature on mail survey length is considered, the results are ambiguous and not conclusive. Some researchers stipulate that online surveys should have 20 questions and no more because the longer the survey the lower the response rate (Rosenblum, 2001). Other studies suggest the length of the survey will not affect responses (Linsky, 1975, Yu & Cooper, 1983). Others suggest a relationship, which links the survey length, response rates and quality, with decreases in both parameters (Yammarino, Skinner & Childers, 1991). While other research shows that even substantive surveys yield considerable response rates and the quality of response is not affected (Deutsken *et al.*, 2004). The inconsistency in opinion within the research literature meant a decision had to be taken.

Accordingly, it was decided to keep the questions short and simple at the beginning. The respondent would not need to exert much effort in answering the questions. The longer more involved responses were employed during the latter stages of the survey (Sue & Ritter, 2012). The introductions to the sections were minimised and provided as lead-ins on the same page with the questions (Sue & Ritter, 2012). Thirty-five questions were asked divided into five topic sections; that ranged from Your Business to Reporting Your Carbon Emissions (see Appendix A).

The ease with which the survey is read also influences the response rate (Couper, 2008). The colour of the survey, navigational aids and the font text needed to be considered as they acted as motivators to reduce survey ‘break-off’ (Sue & Ritter, 2012). To maximise response rates among the target population it is recognised that smaller SMEs on average are least likely to invest in newer information and computing technologies (ICT) (McCann, 2011).

Colours outside the standard 256-colour palette can be altered by the screen’s resolution. A pre-set colour tablet was therefore, used that was within the standard palette and referred to as ‘*Smart Orange*’. The colour orange was chosen because it had high visibility and catches peoples’ attention and served to accommodate potential respondents who may suffer from some form of colour insensitivity (Couper, 2008).

Numerous studies have been undertaken considering font size, readability, reading times and general preferences (Bernard, Liao & Mills, 2001; Bernard, *et al.*, 2002). Arial was used as the preferred option and a font size of 12 and 14 was used respectively (Bernard, Liao & Mills, 2001). The font, style, and size were kept consistent because of the tendency that varying these would cause some respondents to think that others were more important and respond accordingly (Couper, 2008).

To ensure that the survey was respondent friendly, the layout used a conventional questionnaire format however; within that format, a number of response options were utilised. The main

response options selected were radio buttons, matrices, check boxes and open-text boxes. The radio button was used for a closed question when it was necessary to get the respondent to select only one choice from the list. The check box was used in the survey when the respondent was needed to select all the options that applied.

To present several questions that use the same response options a matrix containing Likert-type questions was used (see Figure 3.4). The research into the effectiveness of this response option is ambiguous. Some authors caution against them because the likelihood of missing items increases (Dillman, Smyth & Christian, 2009). Other studies support their use because the matrix question reduces the completion time and the number of missing items in the data (Couper, Traugott & Lamias, 2001); therefore, produces more reliable responses (Sue & Ritter, 2012).

The use of this response option is dependent on the study's objectives. In this instance, it was used in the reporting of carbon emissions to try to get gradation and depth into their responses which cannot be accommodated in 'yes' or 'no' replies. The matrix option was used because it has been noted as reducing scrolling, which is considered burdensome and annoying, and can contribute to early "break-off" (Sue and Ritter, 2012).

**What do you think the reporting of carbon emissions should be based upon
(please provide a response to all in the list)**

	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Employee numbers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Industrial sector	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amount of energy used	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Floor space	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 3.4: A matrix of Likert-type questions used to get gradation in the responses from respondents that ranged from "strongly agree" to "strongly disagree"

Open-ended text boxes; both single and multiline were used when the respondents were needed to provide particular data. The size and type of box was varied and made appropriate with a single line box denoting short phrases and sentences while an added character limit on responses was used to prevent respondents from lengthy statements (Denscombe, 2008). Multiline boxes however, were used when detailed answers and comments were needed, for instance, when asked for a description on the type and numbers of equipment used to provide the service.

The ethos of this survey was that of voluntary participation however, to get respondents to answer as many questions as possible the use of the phrase '*don't know*' was employed. The use of this response mode enabled the respondent to continue with the survey without providing specific answers thereby reducing '*break-off*'. To ensure the design of the survey was suitable for the population of interest it was pre-tested before the launch.

3.2.1.4. Pre-testing and launching the survey

The survey questions were pre-viewed and the survey tested prior to launch. The four pre-viewers were asked to consider the layout, appearance, and respondent friendliness and from the feedback, minor alterations were made to the sequencing of the questions. The survey was then sent to three independent SMEs that were not included in the survey's population of interest, did not have previous exposure to the survey, and tested. The test ensured that the survey could be activated via the hyperlink email; could be completed and submitted successfully. The testing of the survey resulted in no alterations being needed before the launch. The lack of alterations and resource constraints determined that a '*soft launch*'¹ of the survey was not necessary and a '*full launch*' followed.

The launch of the survey was undertaken in a staggered manner on the mornings of Tuesday and Wednesday because these are optimal for professional audiences (Sue & Ritter 2012). The monitoring of responses resulted in the timing of a reminder email being sent 10 days after the initial email survey link. The reminder email contained a hyperlink to the survey and details when the survey closed. The research has shown that timings for a reminder have no significance influence on response rates (Deutsdens *et al.*, 2004). To utilise turnaround times however, it is advised they should be sent early after one week instead of two weeks (Deutsdens, *et al.*, 2004).

3.2.2. Primary data: roundtable discussion

A roundtable discussion is qualitative in approach enabling the '*why*' and '*how*' questions to be investigated to gain an understanding of issues and therefore similar to a focus group. To ensure a robust evaluation of the roundtable findings was undertaken; focus group analytics were used as appropriate. The qualitative research literature informed that the integrity of the results is dependent upon effective planning (Ritchie & Lewis, 2012). Decisions and rationale pertinent to undertaking the roundtable discussion therefore are important and need discussion.

To ensure the data collected from the roundtable discussion is specific to the study objective a questioning strategy was needed because it is necessary in the development of the questioning route

¹ Entails a survey emailed to 1% or 2% of the population of interest, which allows checking for items that may not be functioning well and corrections to be made before the full launch.

and interview guide (Krueger & Casey, 2008; Krueger, 1998a). An appraisal of the literature served as the foundation in developing the questioning strategy, questions, and route. The literature illustrates two different questioning strategies; topic guide and questioning route (Krueger & Casey, 2008; Krueger, 1998a). The former is an outline of a list of topics that a specialist group interview would cover (Krueger & Casey, 2008; Krueger, 1998a). The latter, is a sequence of questions stylised in a conversational manner (Krueger & Casey, 2008; Krueger, 1998a). The topic approach is used by professional moderators and the other preferred by academic environments (Krueger & Casey, 2008; Krueger, 1998a). The researcher was not a professional moderator and in an academic environment therefore, the questioning route was the preferred option and used in this situation.

A questioning route was developed to cover the maximum number of topics to provide specific data, to promote interaction and explore in depth the views and opinions of the participants. To elicit quality responses and assist with the flow of the discussion the questioning route incorporated categories of questions. Five categories of question are considered in the literature to ensure the smooth running of a group interview, which were employed in this approach (Krueger & Casey, 2008; Krueger, 1998a) (see Table 3.1).

Table 3.1: Illustrations for the category of questions used in the roundtable discussion

Category of question	Definition of term	Illustration from the questioning route
Opening <i>[Individual introductions]</i>	Easy to answer, factual, a introductory question to get people talking and feeling comfortable with each other and establish a rapport	<i>'Tell us who you are what type of business you are involved in and what was the best Christmas present you received or gave this year?'</i>
Introductory	Open question that allows for the participant to express a view about a topic	<i>'What term/s is/are in your opinion most effective in engaging with SMEs to monitor and measure their carbon emissions?'</i>
Transition	Links the introductory question to the key question and steers the topic	<i>'What is your experience of monitoring and measuring your carbon emissions?'</i>
Key	Drive the study	<i>'What would we need to change to overcome these/this barrier[s]; can you think of any solutions?'</i>
Ending	Closes the discussion and followed by an overview and ensures that no critical aspects have been overlooked	<i>'Have we missed anything you would like to mention?'</i>

The questions used in the interview guide were open-ended, with the approach being on par with a semi-structured interview to encourage discussion; with probe and follow-up questions being used to elicit additional information. An example of a probe question used is as follows:

'Is there anyone else who has a different opinion with regard to why they think it is a hit?'

The follow-up questions were used to create and bring a different dynamic to the questioning route. The question prior to the follow-up set a baseline while the follow-up was intentional and written into the questioning route, to establish opinion. This is illustrated in the questioning sequence below:

‘Let us talk about the barriers that have been attributed to SMEs reluctance to embrace the monitoring and measuring of their carbon emissions’

[Establish the baseline for the topic]

IF *‘we consider the top three barriers...’*

[Follow-up question that defines the problem]

THEN *‘what would we need to change to overcome these three barriers...’*

[Follow-up question that establishes opinion]

Open-ended questions were used to encourage the participants to respond in their own words; to encourage a wide range of comments; spontaneity and ‘snowballing’ in a bid to set off a chain reaction from other participants (Blackburn & Stokes, 2000). The questioning route encouraged the participants to talk however, to gain greater involvement engagement strategies were employed. The engagement of participants was further augmented using response sheets, prepared flipchart templates and PowerPoint slides. The engagement strategies were used selectively to record responses so as not to stifle conversation, as an *aide memoire* and to provide additional stimuli for the participants to maintain their focus and concentration.

Prior to conducting the roundtable discussion the questioning strategy was discussed with the research team and reviewed to ensure the question phrasing was clear and the sequencing promoted an easy conversation style that was not stilted. The feedback from the team resulted in a few minor amendments being made to the sequencing of the questions. The questions and their route was finalised, a ‘*running order*’ developed which detailed the order, and timings of questions and activities.

3.2.3. Primary data: SME case studies

Nineteen SMEs were approached during the study for data to work with the researcher to enable the assessment of their environmental aspects using RLCAAs (see Table 3.2). The establishments approached, involved a mixture of business activities, from those conducted involving direct physical contact with the customer (customer-facing), to businesses, where activities were conducted online, electronically through the internet (e-business), with no direct physical contact with the customer.

Once the initial contact was made a follow-up telephone call resulted to arrange an initial visit to discuss the research, their obligations if they decided to take part, and the benefits of their involvement. The SME at any point in the ‘*journey*’ could discontinue their involvement in the research (see Figure 3.5.). Subsequently, the engagement with SMEs continued throughout the study, which factored for any discontinuance that could happen. This was a considered strategy because from the nineteen SMEs who had agreed to participate, after the initial discussion and acceptance only three companies completed the ‘*journey*’. The major stages in the case study ‘*journey*’ are illustrated in Figure 3.5. The numbers in the parenthesis denote the stage at which the SMEs chose to withdraw from the study. The numbers in square brackets indicates the numbers of SMEs that ‘*dropped out*’ at that stage.

Table 3.2: SMEs initial agreement to be case studies, the stage at which they discontinued and the reasons

Business id	Services	Stage at withdrawal from the study	Reasons
1	Creative workshops	(1)	Not benefit business
2	Imaging systems	(1)	No time
3	Packaging service	Completed	-
4	Bespoke interior fitters	(1)	Business down turn
5	Festival providers	(4)	Change of management
6	Commercial film making	Completed	-
7	Design, marketing and brand building	(2)	Business closed
8	ICT business intelligence solutions	(2)	Business re-location
9	Design and build websites	(1)	Too busy
10	Seating fitters	(1)	Too busy
11	Family hotel	(3)	Recession
12	Independent film company	(1)	Too busy
13	Email marketing	(1)	Not benefit business
14	Advertising gift consultancy	(2)	Not the right time of year
15	Fingerprint switching service	(2)	Not benefit business
16	Independent bread retailer	(3)	Discontinued product service
17	Community theatre	(4)	Change of direction
18	Drinks retailer	(3)	Business focus changed to eateries
19	Online learning	Completed	
Total completed (%):		~16%	

3.3. Sample selection

The research required the application of differing sampling and selection strategies to ensure that the objectives could be met and the findings would be robust.

3.3.1. Sample selection: online survey

Probability sampling was used to select SMEs. The population of interest was selected from the University's approved suppliers' database, which contained the details for 2,549 suppliers from micro, small, medium-sized and large organisations who were part of the University's *Preferred Supplier Programme* (PSP). The database was utilised for the following reasons:

- Numbers of potential participants
- Integrity of the database; the University is a public sector body they have to comply with strict contracting rules as defined by the EU Directives; on awarding contracts (Directive 2004/18/EC)
- Businesses had to comply with the University's environmental requirements

The database was processed to remove duplicated email addresses and to ensure only those businesses that possessed the following characteristics were included:

- Fewer than 250 employees and comply with the definition for a SME in accordance with the Commission Recommendation 2003/361/EC
- Contactable by telephone
- Personalised email address and
- Have a functioning online business presence; for instance a web page that was 'live'

This process resulted in a sampling frame comprising a target population of 513 SMEs from the University's suppliers database being identified. There are no firm rules about the number of responses although most authors suggest 30 as a minimum to enable statistical applications to be undertaken (Munn & Drever, 2004). In this instance, responses in excess of 30 SMEs were needed to reflect the target population appropriately.

To ensure that adequate responses were obtained 300 (N = 300) potential SMEs were randomly selected from the sampling frame (513 SMEs). This was undertaken in Excel with the initial shuffle of businesses to get a random order and then random numbers were generated and the sample selected. This resulted in sixty-nine (n = 69) SMEs completing the online survey and the findings are presented in Chapter 4.

3.3.2. Sample selection: roundtable discussion

Non-probability sampling, in the form of purposeful sampling was used to ensure data was captured from '*information rich*' (Patton, 2002a,b) employees. Purposeful sampling was necessary to ensure the participants chosen would have the necessary knowledge to contribute to the

discussion. Information rich participants (Patton, 2002a) were needed and selection was directed towards specialist mailing options and contacts.

Three cohorts of recruitment were implemented. The first, used contacts from the pilot survey; the second utilised the Low Carbon South West LCSW mailer² and the third contacts from the FSB. In cohort one; from 22 contacts 11 expressed an interest; from the second cohort; 2 expressed an interest and from the FSB contacts, 2 from the Gloucester and West of England Region³ branch.

Once the selection and recruitment of the group was established the appropriate size of the group needed to be determined; either a small group with fewer than 10 participants or a larger grouping. A larger group was considered inappropriate because of logistical concerns in managing the group and recording the delivered information. A small group was the preferred option because it would enable everybody to have an opportunity to share their views (Krueger & Casey, 2008; Morgan, 1998a,b). To the participants who had expressed an interest telephone and email invitations were used and sent; detailing the time, date and venue and as appropriate confirmation emails; and a day prior to the event reminders were emailed. The findings in Chapter 4 are seen as illustrative of service industry employee's views rather than representing average responses given the size and heterogeneity of the small business population.

3.3.3. Sample selection: SMEs case studies

The case study participants were recruited from direct approaches at business road shows, business breakfast briefing events held by the local FSB, Local Authority, Business Link and the local Chambers of Commerce. The direct approaches ensured that the businesses chosen were '*typical*' (Yin, 2009) in terms of the '*real-life*' characteristics they possessed. Direct approaches were made to nineteen SMEs of which three completed the research '*journey*' providing data that could be used and developed to trial the RLCAAs. The three service industries included a packing, a film and an online distance learning company (see Chapter 5).

The film company contributes to a growing sector that has increased by over 400% in the last 17 years (1996-2012) of which the largest section is in film and video production employing 46,000 people (BFI, 2013). In relation to SMEs parameters, enterprises involved in the production of film and video are typically small, with turnovers less than £250,000, whereby 95% of employers have a workforce of less than 10 people, (BFI, 2012). The industry employs 62,000 people and

² Specialist emailing list sent to 3,000 established business network contacts, which was used to advertise the event.

³ There are 8 regions within this branch; Bristol, Bath, Tewkesbury, Forest of Dean; Stroud, Cheltenham, South Gloucester and Gloucester.

contributed in 2010, £3.3 billion to the UK economy, thereby making a valuable contribution to the British economy (BFI, 2012). At present, there is limited research in the use of life cycle assessment approaches in the film industry. Some commercial literature is in existence however, these are typically single issue focused, and the robustness of the approach coupled with client confidentiality has proved to be a barrier in distilling information thereby, preventing benchmark environmental data from being established.

The online distance learning (ODL) company; which typifies an e-business, that conducts most of its business processes and activities online, electronically through the internet represents a growing market; which has seen applications for part-time courses using this mode of delivery rise by over 40% (Education Today, 2013). The trend is for continued growth within this market, which is assisted by students on ODL courses being offered the same entitlement to tuition fee loans as campus based learners (Education Today, 2013).

The environmental impacts of increasing ODL has received little attention and has only been considered in terms of energy and carbon dioxide emissions (Roy *et al.*, 2008; Hooi *et al.*, 2011). There is a suggestion however, that substituting tangible services with the virtual domain equivalents can assist with reducing environmental impacts (Chowdhury, 2011). The research literature is sparse as to what extent portable technology and the internet can be used to assist with reducing the environmental impacts of the service sector and, currently no systematic study on assessing the environmental aspects of ODL provided by SMEs is evident.

3.4. Data analysis

To determine the findings qualitative, semi-quantitative and quantitative techniques were used to analysis the collected data, from service industry SMEs, owner-managers and employees.

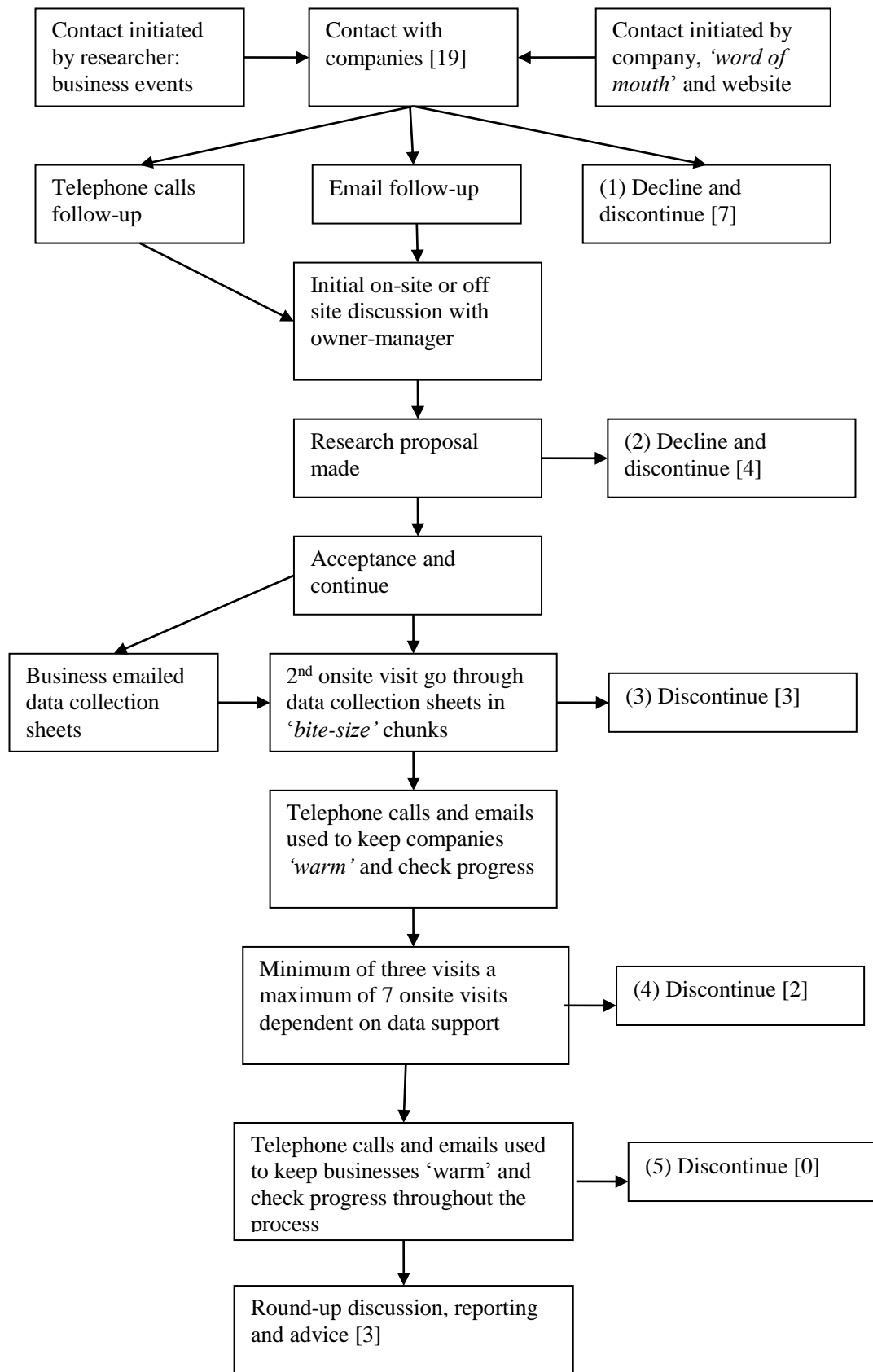


Figure 3.5: The 'journey' of the SME as a case study in the research

3.4.1. Quantitative analysis: online survey

Data collected from the online survey was analysed using descriptive and inferential statistics and Defra/DECC GHG conversion factors from the UK government's online tool as appropriate. Initially, an overview of the data provided from responses to the online survey on waste, energy, transport and the reporting of carbon emissions was undertaken using descriptive statistics and Microsoft Excel (2007).

To determine if there was an association or relationship between the scale of the SME; the type of business premise and the availability of data quantitative non-parametric inferential tests were used as appropriate, using SPSS 21.0 and most notably, Chi-square test for independence and Mann-Whitney U Test (Sirkin, 2005). The tests were considered suitable because they could determine from the presented categorical and continuous variables whether the relationships were significant and not random.

To establish a benchmark value for GHG emissions from the responses to the survey, for the average SME and in accordance with the size of the business, the number of employees that adhered to the EU classification (EC, 2005) was used (see Chapter 2; Table 2.1, p.8). To capture the distinctive group of sole traders, these were handled separately as appropriate. However, where the sample size was too small for analysis the headcount figures used in the classifications were modified. The classifications adopted consisted of the following; sole traders; micro businesses that employed fewer than 10 employees and small and medium businesses that employed 10 employees but fewer than 250 people. Full-time equivalents (FTE) was used as appropriate to account for the part-time employees using the average number of hours worked per week in the service sector (35 hours) (ONS, 2011b) and a part-time average of 18 hours per week.

The quantities and values provided for energy consumption, transport and waste generation and disposal was scaled-up as appropriate to annual estimates and Defra/DECC GHG conversion factors from the online tool was used to estimate emission levels, to gauge a benchmark value for the SMEs (see Chapter 4). Some assumptions had to be made to complete gaps in the data and convert the information to a suitable format for the analysis; to establish a baseline GHG emissions value from the respondents and for the scale of the businesses. The assumptions used in the study are detailed further in the Chapter 4. To the activity data, the quantity values was multiplied by the appropriate emission conversion factor to give an estimate to the amount of GHG emissions being produced (DEFRA, 2013b) (see Tables 3.3.; 3.4.; 3.5; 3.6 and 3.7) and reported as appropriate in relation to the three emission scopes (see Table 3.8).

Table 3.3: Conversion factors applied to energy consumption

Energy	Conversion factor	Unit
Electricity generated	0.44548	kgCO ₂ e/kWh
Energy loss from plant to the SME	0.03809	kgCO ₂ e/kWh
Gas consumption	standard natural gas, 0.18404	kg/CO ₂ e/kWh
Oil for heating purposes	2.538	kgCO ₂ e/litres

(Source: DEFRA, 2013b)

Table 3.4: Conversion factors applied to the disposal and treatment of waste streams

Waste streams (tonnes)	Disposal option	Disposal factor (kgCO ₂ e)
Paper and Board: mixed	Closed Loop (Recycled)	21
Food and drink	Landfill	570
Batteries	Open Loop (Recycled)	65
Plastics: (average plastics)	Open Loop (Recycling)	21
Glass	Landfill	25.7762
Paper and Board: board	Closed Loop (Recycled)	21
Mixed Cans	Closed Loop (Recycled)	21
Commercial and Industrial	Landfill	199

(Source: DEFRA, 2013b)

Table 3.5: Conversion factors applied to fuel

Fuel	Conversion factor	Unit	Price (£/l)
Petrol	2.2144	kgCO ₂ e/l	£1.34
Diesel	2.6008	kgCO ₂ e/l	£1.39

(Source: AA, 2011a,b; DEFRA, 2013b)

Table 3.6: Assumptions and conversions factors applied to business travel by aeroplane

Haul	Distance (km)	Class	Conversion factor with RF (kgCO ₂ e/passenger.km)
Domestic	463	Average passenger	0.326615*
Short	1108	Average passenger	0.192457*
Long	6482	Average passenger	0.226528*

(Source: DEFRA, 2013a,b; Ecolane, 2007)

Table 3.7: Assumption and conversion factor applied to rail travel

Mode of travel	Conversion factor	Unit
National rail	0.04904	kgCO ₂ e/passenger.km

(Source: DEFRA, 2013a,b; Ecolane, 2007)

Table 3.8: Description of scopes

Scope emissions categories	Description
1	Emissions produced from sources owned or controlled by the business; for instance, fuels used in vehicles or boilers
2	Emissions generated from imported purchased electricity, heat or steam, used or consumed by the business
3	Emissions as a consequence of the business' activities, that result from sources owned or controlled by other organisations

(Sources: WRI, 2004; ISO 2006c)

3.4.2. Qualitative analysis: roundtable discussion

There is no agreement as to the rules or procedures used to analyse qualitative data (Krueger, 1998c; Ritchie & Lewis, 2012). The tape recording was transcribed verbatim for analysis and the '*field notes*' incorporated as appropriate along with the responses collated from the flipcharts and response sheets. Subsequently, two differing approaches were used to analyse the data. Where the data could be quantified frequency counts and semantic differential scaling was used as appropriate to establish benchmark values from the data collated through the response sheets and flipcharts feedback. To counter the challenges faced by the analysis of audio qualitative data; best practice, from the Framework approach (Ritchie & Lewis, 2012) was adopted as appropriate, to assign additional content data into topics that arose from the researcher generated questions. The resulting major topics were organised into a narrative summary. The explanations for the findings and recommendations were based on the significance of these results using a mixture of common sense, consensus agreement and drawing in empirical studies to determine the wider application from the evidence presented.

3.4.3. Rationalised life cycle assessment approaches analyses

To address *Objective III*; to assess the environmental aspects on selected SME case studies using rationalised life cycle assessment approaches, two differing life cycle based approaches were employed (see Table 3.9). RLCAAs, by focusing upon flexible selected environmental impacts; particular stages in the life cycle or using models or databases can be utilised by SMEs. Accordingly, two differing RLCAAs were trialled on data collected from three-service industry SMEs (see Table 3.9).

Table 3.9: Overview of the two RLCAAs showing the main practical and technical features

	Rationalised Life Cycle Assessment Approaches (RLCAAs)	
	Magnitude Approach	Pragmatic Approach
<i>Features</i>		
<i>Tool</i>	SIMAPRO	Matrix
<i>Computation</i>	PC-based	Calculator
<i>Perspective</i>	Hierarchical (H)	Graedel (1998)
<i>Environmental relevance</i>	Impact categories	Environmental concerns/stressors
<i>Technique</i>	Quantitative	Semi-quantitative
<i>Method</i>	ReCIPE	Protocols & guidelines (Graedel, 1998)

3.4.3.1. Quantitative analysis: magnitude approach

Data was collected working in partnership with owner-managers from the service industry SMEs on an identified functional unit within a defined boundary for a service undertaken by their business. The setting of the *system boundary* in theory should include all upstream and downstream stages of a service however, this is unrealistic. Given that no choice of boundary is correct, (Boustead and Hancock, 1979) the boundary for each case study was established and was

dependent upon the aims, available resources, the ease of data availability and management and operational responsibility. This was particularly important for SMEs who have limited resources. Once the goal and scope had been established data was collected to create an inventory table of the energy, materials used and wastes produced for the service over its life cycle in the context of its functional unit (ISO, 2006a). In all of the case studies, preference was given to the collection of primary, site-specific data for processes controlled, owned or operated by the SME, which were relevant to the system boundary of the service being assessed.

Secondary data, which consisted of peer reviewed publications and proprietary databases for instance Ecoinvent was employed when the collection of primary data was impractical and not possible, because of resource constraints or the reluctance of suppliers to provide information that they deemed confidential. In this instance of data quality, the researcher was mindful of data integrity in the development of the inventory. Accordingly, data quality and indicator parameters were collected mindful of life cycle assessment based requirements and guidelines (ISO, 2006b).

In terms of the data, the type of modelling and data quality parameters needed to be established because they would affect the overall assessment and interpretations and influence the way in which the data was evaluated, gathered and collated. In the case studies, the modelling and development of the inventory was largely consistent with an attributional life cycle assessment approach (ALCA). ALCA was adopted because it enabled average data to be used and accorded with goal and scope parameters that influenced the system boundary, meaning it was more suitable than a consequential approach (Finnveden, *et al.*, 2009).

The data in the inventory was assessed in terms of its environmental burden across selected impact categories. The impact assessment phase '*translates*' the environmental impacts into a form that can be understood by the SMEs (Rebitzer, *et al.*, 2004). During this phase, the following steps are considered: *a) category definition, b) classification and c) characterisation*. (ISO, 2006b);

a). Category definition refers to the impact categories selected, the linking of those categories at mid-point or end-point and characterisation models. The services were initially considered in terms of their burden on the following impact categories (Guinée, 2002)

- *Abiotic resources*; which was used to consider the effects of the services on non-living resources, for instance the depletion of fossil fuels
- *Climate change* often referred to as global warming; this category was used in assessing the impact of the services in terms of the 'greenhouse effect'

- *Stratospheric ozone depletion*; this impact was used to denote the effect of the services in terms of its contribution to the decomposition of ozone which can cause an increase in UV radiation, impacting upon peoples' health for instance, in the form of skin cancer
- *Land use*; was used to determine the impacts of the services upon loss of biodiversity and as a resource
- *Eco-toxicological impacts*; this impact was chosen because it assesses the toxic effects the services have on all species not just humans
- *Human toxicological impacts*; this was used to show the effects of the contribution of the services' chemical and biological substances their emissions on the effects of people
- *Photochemical oxidant formation (smog)*; this impact was chosen because it details the effects of the services on ozone formation which can lead to health problems and photosynthetic function damage
- *Ionising radiation*; was selected to determine the impact of the service in the release of radioactive substances
- *Acidification*; was considered because in terms of the service provided it details the potential 'acidification' effect of the given production processes involved with the services
- *Eutrophication (nutrient enrichment)*; this category was chosen to assess the effect of the service on aquatic and terrestrial ecosystems in terms of surplus nitrogen, phosphorus and degradable organic substances which potentially affects the changes in function and diversity of species

b). Classification then aggregates and assigns the inventory data from the case studies with separate selected impact categories (ISO, 2006b) for instance, climate change. Once the impact categories are defined and inventory results assigned; the characterisation step is used.

c). Characterisation, identifies the potential magnitude of the emissions, allocating the relative contribution of inputs and outputs from the selected impact category (ISO, 2006b), in terms of the problems created for the environment. For instance, in terms of climate change, the contribution that the emissions make, specifically carbon dioxide, to global warming potential. The process is founded on environmental factors, involves scientific analysis and is mostly quantitative. The integrity of the equivalency (magnitude) factors however, is variable and although there is a consensus about global warming potentials and ozone depletion; there is not a consensus available for land use or biotic resources, which considers the effect of the service on living elements within ecosystems (Guinée, 2002; Lindeijer, Muller-Wenk & Steen, 2002). This discrepancy in the assessment profile needs to be considered when interpreting the results and deciding upon the relevance of impact categories to SMEs.

The inventory data was processed using an impact assessment methodology, ReCiPe. This methodology was used primarily because it combines two groups of impact categories and their characterisation factors; CML and Eco-Indicator 99 and shows both mid and end-point characterisation; it is relatively new assessment method and its data sources have a global and European perspective (Goedkoop *et al.*, 2009). The assessment methodology was of benefit to the study because it possessed the following attributes:

- Ability to assess to midpoint and endpoint
- Up to date characterisation (to highlight the biggest contribution) and normalisation data (significant impact categories)
- Used in and with Open LCA

There are a large number of commercial software packages on the market that have been developed to process the data. The software packages differ in the data that is made available and its source; how it can be accessed (Trusty & Horst, 2005) and its cost. In this study, the software used was SimaPro (PRé Consultants, 2008a). This software tool was used for the following reasons:

- It was accessible
- Flexible in the way data could be analysed and interpreted
- Largest number of inventory databases and impact assessment methods
- Well integrated with the Ecoinvent database
- Allows the LCA to comply with international standards
- Familiarity with Open LCA
- Off-the-shelf LCA software is popular, used by 69% of LCA practitioners (Cooper & Fava, 2006)

The SimaPro software contains a number of inventory databases, which provides life cycle information on processes and products (PRé Consultants, 2008b). Where data specific to the SME could not be collected from suppliers and purchasers to quantify their inputs and outputs, data from databases was used to create the model. In relation to SMEs, this can make a life cycle based approach a quick and simple environmental analysis tool however; it can be costly where purchase is required. The main database used was Ecoinvent, version 2 (Ecoinvent, 2007; Frischknecht, *et al.*, 2007; Faist, Heck & Jungbluth, 2003) for the following reasons:

- Ability to add own primary data that can be specified to match the SMEs cases
- Data sources are transparent as is data uncertainty
- Impact categories are relevant to the study

- Consistent application of system boundaries
- Database is familiar to Open LCAs

The other databases used to much lesser degrees, where appropriate data could not be found for the development of integrated models were, IDEMAT 2001 and BUWAL 250 (PRé Consultants, 2010). The former database was developed by Delft University and is based on Dutch sources. IDEMAT was used when data on alloys and specific wood types was needed within the system and because it was based upon the Ecoinvent inventory (Vogtländer & Segers, 2011). The latter was developed by EMPA and is founded upon Swiss data (Emmenegger, Heck & Jungbluth, 2003).

The inventory data assessed using ReCiPe, in each of the case studies the midpoint impact category was used, to identify issues of environmental relevance. Initially, all 18 impact categories were assessed, but this was reduced to 10 impact categories as low importance impact categories; and those with fledging science for instance, land use, eco toxicity and human toxicity (Guinée, 2002) were excluded from the analysis. The characterised results were used to identify the biggest contribution to impacts and normalisation used to identify important impact categories and to enable comparisons to be made between each impact category. This enabled the impact category results from characterisation to be compared with a standard value thereby limiting the influence of value-based choices or judgements.

In this instance, the results are normalised based upon the emissions caused by the average European per year (PréSustainability, 2011). The use of this element allowed the results to be compared to one reference point and significant impacts to be identified; enabling the order of magnitude of the environmental impacts caused by the system under study to be detailed in terms of average European emissions (Wegener, *et al.*, 2008).

The results from the assessment were used to identify the significant issues, in relation to the impact categories and significant contributions from the life cycle stages (e.g. travel) and using predominantly contribution analysis to identify the environmental issues (ISO, 2006b). In addition, conclusions were drawn, limitations of the assessment identified and recommendations made to reduce impacts (ISO, 2006b).

3.4.3.2. Semi quantitative analysis: pragmatic approach

The matrix assessment was developed in the 1990s to abridge full life cycle assessment, because it was, '*difficult to relate inventories to defensible impact analysis and translate the results of those stages into appropriate actions*' (Graedel, Allenby & Comrie, 1995).

The framework followed as delineated by Graedel (1998; Graedel & Saxton, 2002) in this assessment consisted of four main life stages (see Figure 3.6). Stage 1 involved considering the significant impacts that concerned the site or facility itself for instance, how it was selected, developed and its infrastructure (Graedel, 1997; Graedel, 1998). The service provision stage acknowledged the impacts of '*in-use resource consumption*' (Graedel, 1998) for instance, computers, office machines, supplies, vehicles and the developing and operating of the service. Stage 3 is sub-divided into 3a and 3b; the former dealt with the actual operations of performing the service to end-users (Graedel, 1997; Graedel, 1998). In this stage, the relevant environmental stressors that needed addressing were the environmental implications of energy consumption and transportation. The latter, facility operations dealt with the on-site operations at the facility, for instance, transport, energy use and waste materials (Graedel, 1997; Graedel, 1998). At stage 4, the closure of the service or facility is addressed and this varied depending on the service however, it is flexible within the approach and can be assessed as the end of a plan to erasing files from the memory of a computer (Graedel, 1998; Graedel, 2003).

The stages of the life cycle for each case study were considered in relation to a series of environmental concerns or stressors. In relation to the service's activity, the stressors included choice of materials, energy use, and gaseous, solid and liquid residues (Graedel, 1998; Holmberg, 1999). Properties for each of the environmental concerns / stressors were evaluated against a series of protocols, which are presented by Graedel (1998).

A value for each element in the protocol was assigned a rating; zero equated with maximum environmental concern or stresses to four least or no concern (Graedel, 1998; Masoni, *et al.*, 2004). To enable potential comparisons to be made within the discipline, the values attributed to the environmental impacts for each case study was as follows; zero, severe environmental concerns; one, significant; two, moderate; three, marginal concerns or insignificant and four, no concerns.

A rating of zero would involve for instance, the used of hazardous or virgin materials that would alter the environment; or there were no attempts made to reduce the resource levels although alternatives exist. One (significant) would include as an instance, the development of a Greenfield site or the wasteful use of resources with no evidence of reusing materials. A rating of two (moderate), would include the energy or materials use in or by equipment, with some evidence of avoiding or minimising resources. Marginal or insignificant concerns were allocated where slight modifications, as is practicable to the businesses is needed to the infrastructure or minimisation schemes. A rating of four, (no environmental concerns), was determined where there was evidence of the effective management of all resources, the choice of materials, energy used and gaseous, solids and liquid residues.

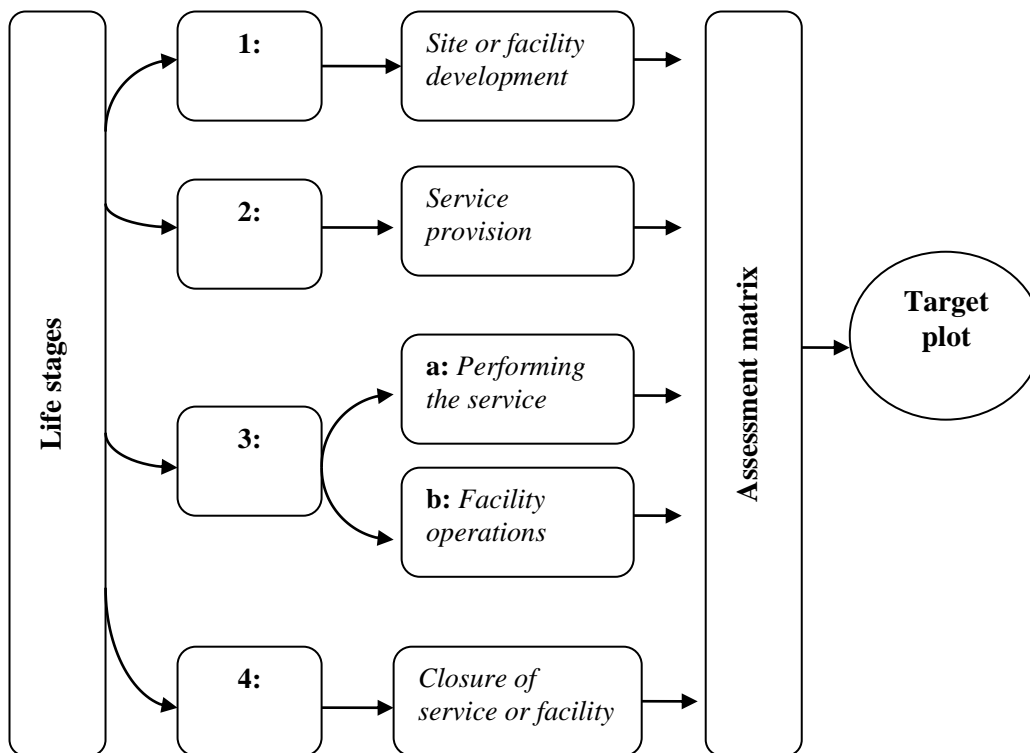


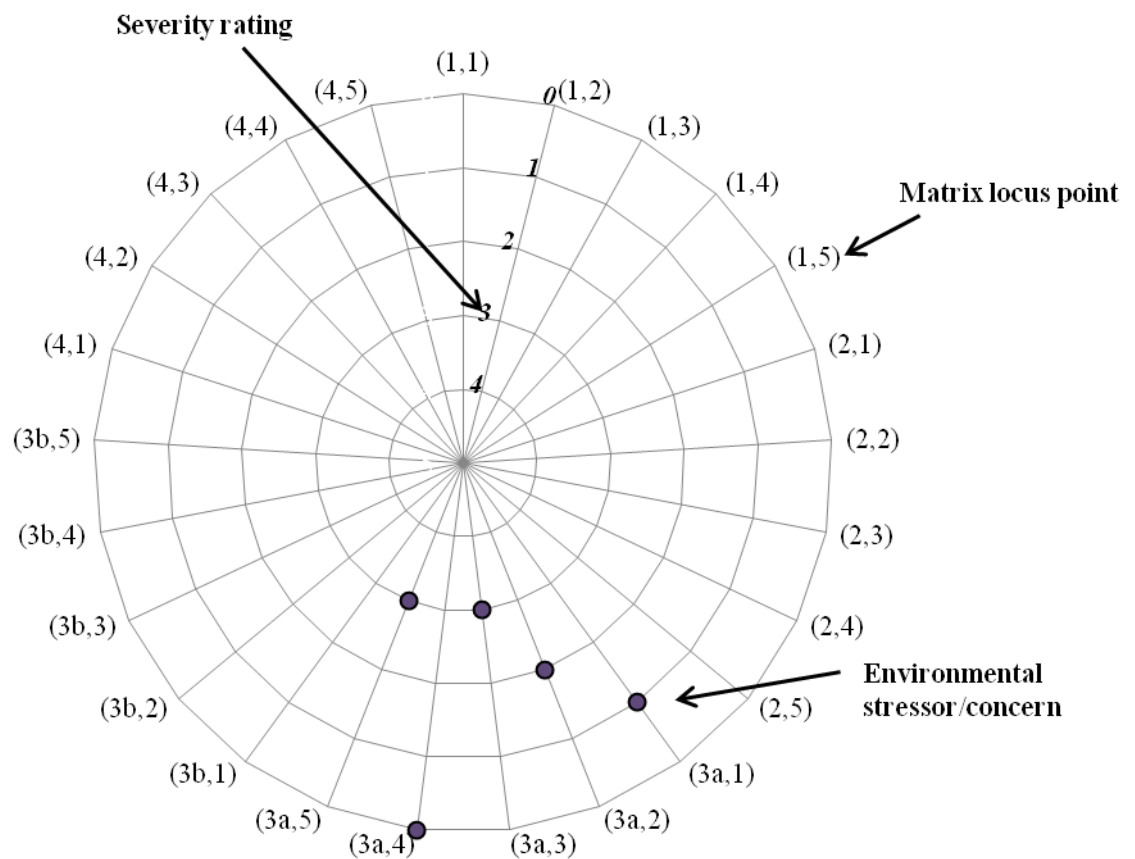
Figure 3.6: Stages followed in the service assessments (Source adapted from: Graedel, 1998)

Once the elements were evaluated, an environmentally responsible service rating was calculated for the overall system (Graedel, 1998). The rating was calculated by totalling the values attributed to the matrix elements. The twenty-five elements meant, the highest score a SME could be rated was hundred (Graedel, Allenby & Comrie, 1995). This resulted in the development of a 5 x 5 assessment matrix (see Chapter 7). The results from the assessment matrix were used to construct a 'target plot', which illustrated the environmental concerns and stresses within the system (Graedel, 1998) (see Figure 3.7). In figure 3.7, the linear diagonal separators are the matrices loci points. The circular rings within the plot area, the matrices element values signifying the environmental severity.

A demonstration of a high achieving environmentally responsive service or SME is denoted as a series of dots clustered around or in the centre (Graedel, Allenby & Comrie, 1995). The environmental concerns that need addressing within the system are those distant from the centre, which enables their activities to be prioritised. The points distant from the centre of the target for the case studies were addressed in conjunction with the appropriate checklist and protocols. Recommendations were made on how to improve the individual matrix element rating, thereby addressing environmental concerns within the SME and potentially improving their environmental

performance. The recommendations were applied to the matrix assessment and the differences compared.

In accordance with limited sample size studies, the findings are considered from a case study perspective (Graedel, 2003) and an analytical as opposed to a statistical logic is used (Yin, 2009). Each case study is analysed independently using the two RLCAAs. To ensure the assessments can be analysed comparatively the goal, scope, functional unit, boundaries, data collection and assumptions were generic for the approaches but specific to the provided service. The overall service boundaries for the case studies is comparable to life stages 2, 3a and 3b, however, for comprehensiveness life stages 1 and 4 were included and being discrete stages their concerns and stressors did not affect the definitive service boundaries. This enables the findings to be compared and contrasted thereby determining their suitability for service industry SMEs.



Life stages: Facility/site development (1); Service provision (2);
Performing the service (3a); Facility operation (3b) & Service/site closure (4)

Figure 3.7: Target plot showing the constitute elements

3.5. Summary

In this chapter, the research approaches, strategies, and techniques are presented. The interdisciplinary nature of this research and objectives determined a combination and application of approaches, strategies, and techniques. The research details and rationale for use is summarised in Table 3.10. Further details on the application of the approaches and techniques are included where appropriate in the relevant chapters. In Chapter 4, the results from the online survey using descriptive and inferential analysis and, from Defra/DECC GHG conversions as appropriate are presented; in addition, to the findings from the facilitation of a roundtable discussion using focus group analytics. In Chapter 5, details of the models for the three service industries, the packing, filming and online distance teaching (ODL) companies on which the two RLCAAs are trialled is defined. In Chapter 6 and 7 results from the RLCAAs, which assesses the environmental aspects for the services to determine the potential impacts, is reported for the magnitude and pragmatic approaches respectively.

Table 3.10: Summary of the research approaches with rationale

Type	Sample size	Technique	Details
Pilot study	22	Quantitative	<p>Study conducted to explore the levels of, and approach to, environmental activities amongst SMEs.</p> <p>Conducted because of the need to establish current trends among SMEs, find secondary evidence to complement the literature review & identify further research.</p> <p>Data collected from on site interviews with owner-managers, using a face-to-face questionnaire. Excel (2007) used for quantitative analysis on aspects of the data that was relevant in exploring types of environmental activities & Palmer classification (2000) used to determine the level of and approach to environmental activities.</p>
Online survey	69	Quantitative	<p>Survey administered online so that values for fixed data indicators for energy, transport, waste generation and disposal and units of equipment could be collected directly from owner-managers.</p> <p>Undertaken because of the need to identify the type of environmental data available that can be feasibly submitted online and used to report the amount of GHG emissions being produced; to establish baseline emission values. In comparison with paper-based questionnaires online surveys are noted for obtaining greater accuracy to knowledge questions; have higher completion rates; generate information that is more complete and with fewer missing responses; and limited the influence of interviewer effects.</p> <p>Frameworks developed outlining the processes to conduct an online survey; and one detailing developing, designing & deploying a survey using survey software. Surveys emailed in accordance with frameworks developed and data collected.</p> <p>Excel (2007) & SPSS 21.0 used for descriptive and inferential statistics in quantitative analysis on data relevant to its availability, environmental aspects and scale of the businesses.</p>

Type	Sample size	Technique	Details
Online survey (continued)			System developed that included energy, equipment, waste generation and disposal; & emissions to water and air developed from the environmental data submitted. To the environmental data, Defra/DECC online conversion tool used and factors applied since it is the advised factors for use with UK SMEs by the government. To quantities of waste, initially volume weight conversion factors applied to determine waste generation values, then with energy consumption, fuel use, travel activities & waste disposal converted into GHG quantities and expressed in Scopes as appropriate. The technique used to establish an average baseline GHG emissions value per annum for SMEs and values for each of the three-business scales, sole, micro, small and medium.
Roundtable discussion	7	Qualitative	<p>Discussion held in order to establish and uncover the views and opinions of service industry employees from a '<i>bottom-up</i>' perspective.</p> <p>Undertaken because of the need to '<i>hear</i>' from operational staff who are instructed to implement procedural changes to ask '<i>what</i>', '<i>where</i>' '<i>why</i>' and '<i>how</i>' questions and get participants to discuss topics in their own language thereby, gaining different information with acknowledged greater integrity that cannot be obtained from surveys and one-to-one interviews.</p> <p>Information rich employees from service industries recruited from FSB and from those who replied to an advertisement placed in the LCSW mailer. A questioning route and strategy was developed and adopted as this is the preferred option in academia and is noted for eliciting quality discussion and debate. The discussion was audiotaped and transcribed and '<i>field notes</i>' incorporated. The data was analysed; where data could be quantified frequency counts and semantic differential scaling was used as appropriate; for the qualitative data, best practice from the Framework approach was adopted to assign content data into topics or themes. The findings were organised into a narrative summary with descriptions and representative data illustrations as appropriate and discussed within the context of the SME environment.</p>

Type	Sample size	Technique	Details
RLCAAs: magnitude approach	3	Quantitative	<p>Approach adopted using the SIMAPRO tool in order to assess the environmental aspects on selected SME case studies to determine impacts. Tool used because of access to the ReCiPe methodology and the inventory databases, for instance, Ecoinvent; its <i>off-the-shelf</i> popularity and familiarity with open LCA; impact categories relevant to the study.</p> <p>Primary data collected from SMEs, guided by the ISO framework; system developed, from agreed functional unit within a defined boundary for a service undertaken by the company. Inventory table developed with modelling consistent with an attributional approach (ALCA). Impact categories selected, ReCiPe methodology applied at midpoint (H) (E); results evaluated, scenarios developed & recommendations made.</p>
RLCAA: pragmatic approach	3	Semi-quantitative	<p>Approach adopted using a matrix tool so as to assess the environmental aspects on selected SME case studies to determine impacts.</p> <p>Tool used because it enables a pragmatic approach to be taken as opposed to a magnitude approach and is juxtaposed theoretically, technically and practically; to effectively establish which approach is suitable for SMEs.</p> <p>System developed, functional unit and defined boundary for the SME identical to the magnitude approach. Data used however, to develop an environmentally responsible service assessment rating by life stages; based upon scoring guidelines and protocols guided by Graedel (1998), expressed in terms of four service industry life stages relative to environmental concerns/stressors, and ranked from 0 to denote a severe concern through to a rating of 4, no environmental concerns presented. These element values used to create a 5x5 service industry life stage assessment matrix. The results interpreted and expressed in a target plot, scenarios developed & recommendations made.</p>

Chapter 4

Results: SME Benchmarking and Perceptions

This chapter presents first, the quantitative analysis and results from an online survey and then analysis from a qualitative assessment for a roundtable discussion. The former, used data gathered and collated from sixty-nine service industry SMEs owner-managers' submissions to an online survey, initiated in September 2011; the latter, used data collected from seven employees working in service industries undertaken in January 2012.

This chapter therefore, addresses *Objective I* and *II*. The former, objective seeks to identify the type of data available from owner-managers of service industry SMEs that can be used to report the amount of GHG emissions being produced. The information is used to establish the availability and accessibility of emissions data; to determine the amount of GHG emissions being produced by service industries and distinguish reduction strategies through which SMEs can identify cost saving opportunities and efficiency improvements.

The latter *Objective*; to establish the views and opinions of service industry employees from SMEs to measuring, managing and reporting GHG emissions; information is sought to distinguish the views of employees from an operational and procedural perspective; to enable greater participation with the reduction of emissions as society moves towards an increasingly low carbon agenda.

4.1. Quantitative analysis: online survey results

The owner-managers were asked if they could provide data on seven activities related to features identified in the GHG Protocol. The data variables were weighted towards Scope 3 (see Figure 4.1) because this is where the bulk of the emissions lie and data is difficult to obtain. The findings (see Table 4.1) show for the presented Scope 3 data parameters, nearly three-fifths (57%), indicated that data asked for could not currently be provided, or they were unsure. However, just over a third (39%) could provide data for the Scope 3 parameters (see Table 4.1.).

Table 4.1: Responses from owner-managers on their ability to provide data Scope 1, 2 and 3 emissions

<div>Data / Scopes</div>	Data currently available & accessible	Data currently unavailable & inaccessible	Unsure of data availability & accessibility	Skipped/non responses	Totals (%)
Scope 1	65	22	13	0	100
Scope 2	64	26	10	0	100
Scope 3	39	41	16	4	100

In terms of the specifics in relation to the activity data figures, Figure 4.1 shows the findings in detail. The three main activity parameters that the SMEs could provide data for were; the distance

travelled in company vehicles, (65% of respondents); the amount of electricity, (64%); and business distance travel by employees, (59%). In this instance, data can be provided for emissions categorised under Scope 1, 2 or 3. Scope 3 activity data that the businesses would find difficulty in currently obtaining was the transport distance of their business' waste (*aggregation of data unavailable and unsure*), with nearly four-fifths of businesses, 75% reporting difficulties. While, over three-fifths, (70%) reported they would have difficulty in obtaining data for the production and manufacture of materials used by the business, and 59% for generated business waste.

The findings were considered in relation to the scale of the business relative to the availability and accessibility to emissions activity data. Figure 4.2 shows descriptively the responses of the businesses relative to their scale to scope data parameters. The findings showed that the majority (55%) of micro businesses, (*aggregation of data unavailable and unsure*) would not be able to provide data on the selected scope categories and would struggle. The majority of small and medium businesses, (56% and 61% respectively) could provide data on the listed scope categories.

In terms of the responses to specific scope data parameters, 56% of micro businesses could provide data for the distance travelled in company vehicles. Over three-quarters, (81%) of micro businesses responded that Scope 3 data was unobtainable (*aggregation of data unavailable and unsure*) for the transport distances for their business waste. The majority of small businesses, 75%, had data available and accessible for the amount of electricity used by their businesses but would not be able to provide data for the transport distances for their business waste. Sixty-five percent responded that this data was unavailable, inaccessible or were unsure of its availability. All of the medium businesses were able to provide data for the distances travelled in company vehicles; however, 88% could not provide data or were unsure of data accessibility concerning the production and manufacture of materials used by their business.

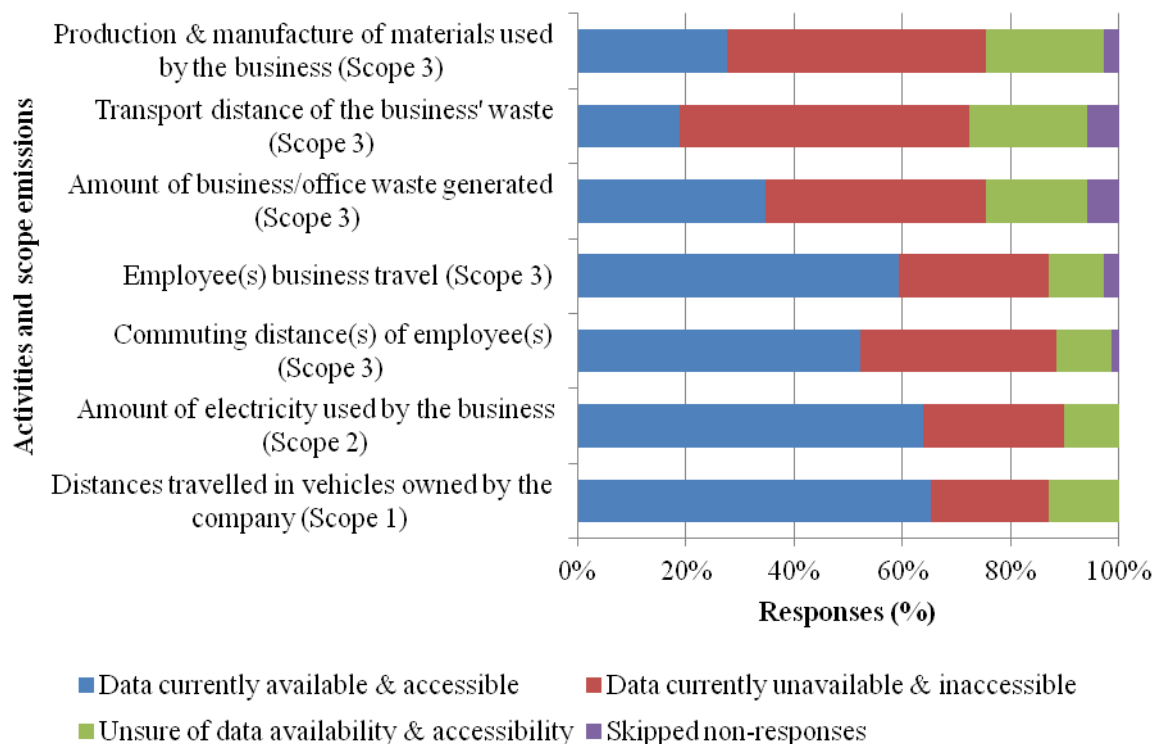


Figure 4.1: Responses from owner-managers on the ability to provide data for Scope emissions activities (n = 69)

To determine if the type of business premises the service operated from or whether the scale of the business influenced the availability and accessibility of data; inferential statistics was used to test for significance and associations. The results of the analysis from the activity data revealed that the availability and accessibility of Scope 1, 2 and 3 data variables were not significantly associated with the scale of the business and where permitted the type of business premise in which it was sited (see Appendix B: Tables 4-1 and 4-2). The results from the Chi-square test for independence for waste where permitted showed no significant association between the availability and accessibility of waste data in terms of the scale of the business and the type of business premises (see Appendix B: Tables 4-3 and 4-4). The owner-managers however, had the ability to supply information on energy consumption, waste disposal, business travel and capital items, which were used to establish baseline emission levels for, the SMEs.

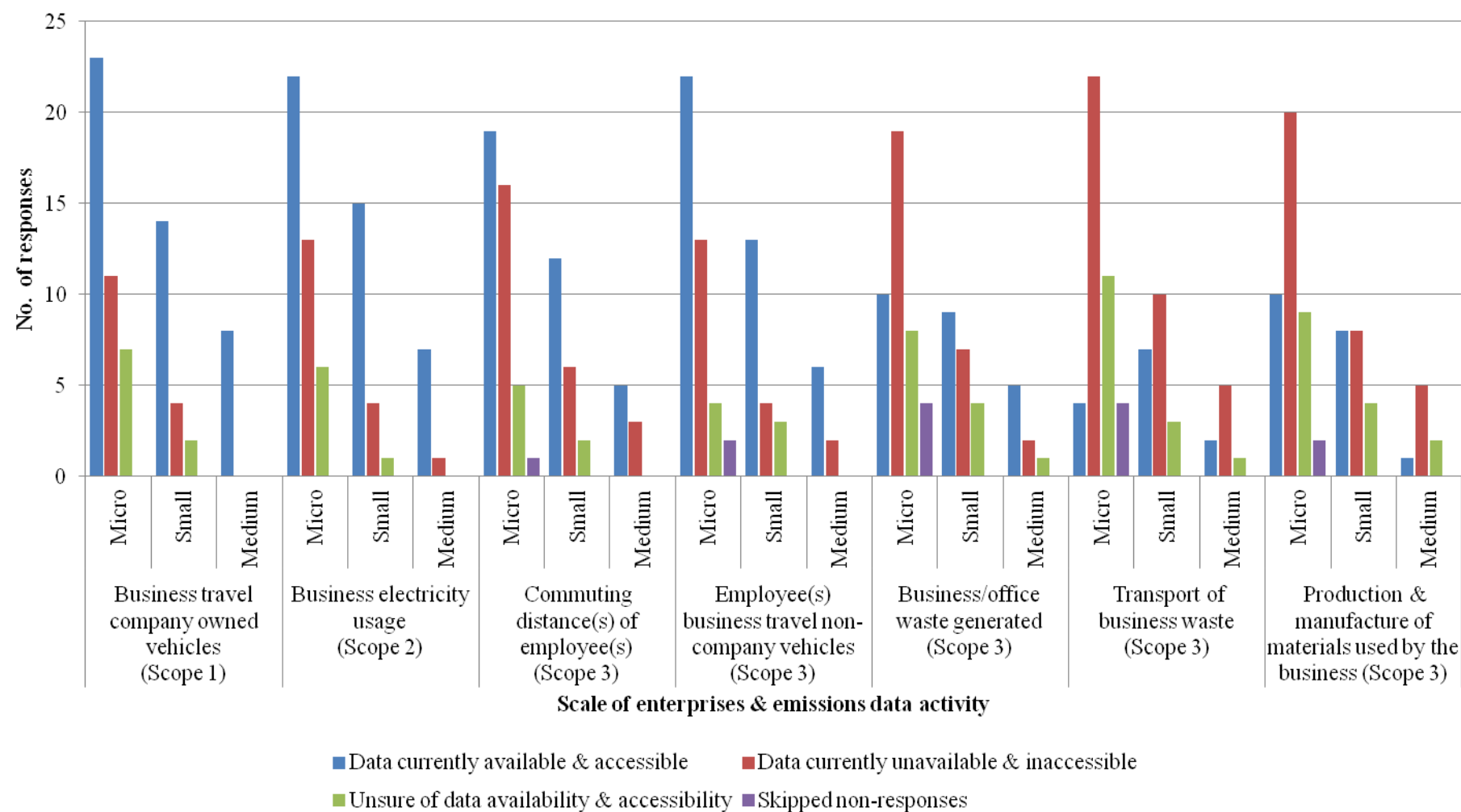


Figure 4.2: Responses to selected scope activity data, its availability and accessibility relative to the scale of the SME

4.1.1. Establishing a GHG emissions baseline

To determine and configure a baseline emissions value for each business scale, quantifiable data needed to be obtained and measured. The computation of an emissions baseline had the added benefit of assisting with determining what reduction strategies could be feasible for the service industry businesses. The survey asked the owner-managers to provide data on energy use, transport use, waste generation and disposal and capital items. A generic system boundary was developed (see Figure 4.3) and the assumption was made that the data provided was based on parts of the business that the owner-managers perceivably had control over or owned.

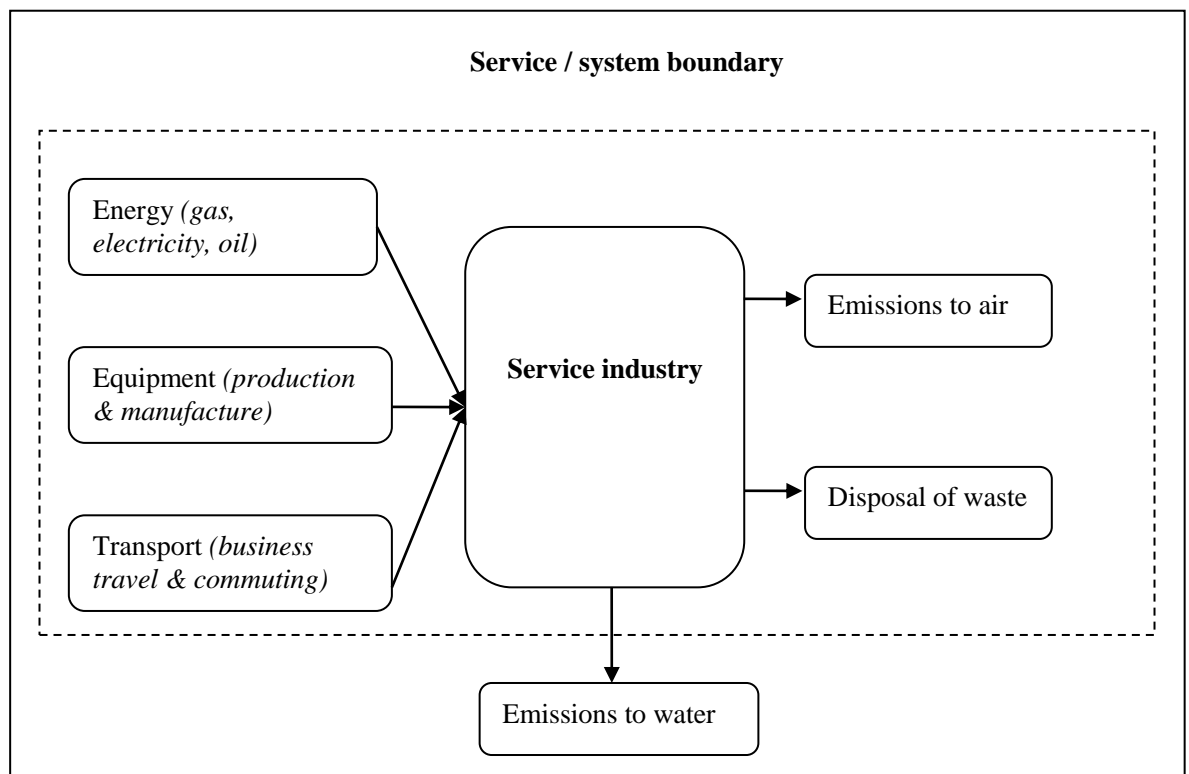


Figure 4.3: System boundary used in the assessment

The businesses were separately studied in relation to scale and were compared as appropriate. The business activities were broken down into service components relative to Scopes 1, 2 and 3. The activities for which data was provided were identified (see below) and converted into GHG emissions following the DEFRA's guidelines and conversion rates (DEFRA, 2013b):

- Gas consumption (Scope 1)
- Electricity consumption (Scope 2)
- Waste disposal (Scope 3)
- Travel (Scope 1 and 3)
- Capital items (*relating to the production and manufacture of equipment*) (Scope 3)

4.1.2. Data and assumptions

In the establishment of a baseline GHG emissions value a number of assumptions needed to be applied to the data from the respondents to the online survey. The assumptions applied to the data in respect of determining their GHG emissions are outlined in the following sections.

4.1.2.1. Energy consumption

To determine annual energy consumption for both of the utilities electricity and gas and to ensure an effective response, consumption was bracketed and classified within the terms of less, between, greater than or '*I do not know my annual consumption*'. To obtain a value for these bracketed kWh *readings* the upper limit for less than and between was used; for instance, if a respondent replied that their annual electricity consumption was between 10,001 and 12,000 kWh a figure was 11,999 kWh was used. In relation to the *reading* responses; greater than 12,001 kWh the figure 12,002 was used. The same approach was applied to the responses given to the *readings* for annual gas consumption. It is realised that this approach in some cases is over-estimating and under estimating the consumption of energy used however, as a method it suffices in establishing a baseline value.

To convert the kWh values to kg of GHG emissions, for the electricity generated the appropriate conversion factor was applied and the value assigned to Scope 2 (see Chapter 3, Table 3.3: p.47). The energy loss that resulted from getting the electricity from the plant to the business was calculated using equally the appropriate conversion factor and attributed to Scope 3 (see Chapter 3, Table 3.3: p.47).

In terms of gas consumption, GHG emissions were obtained by applying the conversion factor for standard natural gas, and assigning this value to Scope 1 (see Chapter, 3, Table 3.3: p.47). Some of the respondents reported that they used oil as a heating fuel. Accordingly, their annual unit measurements given in litres were converted to kgCO₂e/litres by using the appropriate conversion factor, (burning oil used for heating purposes) and assigned to Scope 1 in further analysis as it was deemed in this instance to be a primary fuel source and combusted on site.

4.1.2.2. Waste generation and disposal

To try and ensure that the businesses could provide as much information on the waste generated and its disposal; quantities were obtained by asking the owner-managers to give the amount of business waste they disposed of for the week ideally as a measured weight in kg/week or alternatively as a description, for instance, 15 sheets of A4 printed paper. In terms of both modes of responses, the quantities of waste generated and disposed of were scaled up to provide annual values. To provide a unit weight to the descriptions of waste provided by some respondents a number of assumptions were employed and these are outlined in Table 4.2.

Table 4.2: Assumptions and unit weight values applied to the descriptions of waste

Description of waste	Assumptions	Unit weight
Magazine	Based upon randomly weighing ten magazines and using the average weight and applying this to a magazine description	175 grams per magazine
One sheet of A4 paper	Determined from the weight of a pack of A4 uncoated sheets, weighing 2.5kg containing 2,500 sheets	1 gram per sheet of A4 paper
Battery	Ascertained from the average weight for alkaline AA cells	23 grams per battery
Plastic bottle,	Based upon a 1.5 litre water bottle comprising of both PET and PP materials	40 grams per generic plastic bottle
Glass bottle	Established from a 330ml bottle	190 grams per generic glass bottle (Mohan, 2013)
Cardboard box	Determined from a 18x18x18 carton and a worst case scenarios	1,139 grams per cardboard box (WRAP, 2005)
Aluminium can	Ascertained from an average empty 330ml beverage can	14 grams per generic aluminium can (PYR, 2013)
Flip chart paper	Based upon A1 plain 40 sheet packs weighing in total 1.1kg	27.5 grams per sheet of paper
Empty plastic milk cartons	Based upon the average weight of two pint plastic milk containers	25 grams including lid
A4 boxes	Based upon a 12x9x9 box	318 grams (WRAP, 2005)

In terms of bin bag responses to waste disposal questions two operational modes were followed. The first was to convert responses of “2 bin bags” into litres then cubic metres, scale up for an annual quantity and then apply a conversion factor specific to the type of waste in relation to the annual quantity. A small bin bag was assigned a volume capacity of 40 litres (0.04 m³); a medium bag, 60 litres (0.06 m³) and a large bag 80 litres (0.08m³).

Where no size of bin bag was stipulated as in the above italic response, medium units were attributed. The rationale for assigning size in this manner is attributed to after 80 litre bags, two-wheeled bins become available and manual handling issues prevail. Subsequently, the waste is likely to exceed 16kg after 80 litre bags when two-wheeled bins are used. The main volume weight conversions factors applied relative to the type of waste produced is summarised in Table 4.3.

Table 4.3: Volume weight conversion factors applied to types of generated waste

Type of waste	Volume weight conversion factors	Sources
Kitchen waste (food)	0.20 tonnes per cubic metres	EA, 2002
Paper and card	0.21 tonnes per cubic metres	EA, 2002
Plastics	0.14 tonnes per cubic metres	EA, 2002
Glass	0.33 tonnes per cubic metres	EA, 2002
Office waste	0.10 tonnes per cubic metres	EHS, 2000

The waste for each stream once converted into tonnes specific waste disposal factors were applied to obtain the amount of GHG emissions. Waste disposal factors were applied relative to their waste stream and disposal option (see Chapter 3; Table 3.4: p.47) and the findings applied to Scope 3 (see section 4.1.3, p.70).

4.1.2.3. Travel

To determine the emissions from transport for business purposes, the estimated annual fuel use and units of measurements was provided by the respondents. An alternative option was made available where this was not feasible to the respondents. In this instance, the respondents were given the opportunity to provide estimates based upon their expenditure in pounds sterling for the fuel purchased.

The estimated annual use of fuels used was converted to litres and appropriate conversion factors for petrol and diesel applied (see Chapter 3; Table 3.5: p.47). In instances, where the value of the fuel was given in pounds sterling the price for a litre of petrol and diesel was in accordance with the Automobile Associations (AA) annual averages fuel price reports (AA, 2011a,b). Accordingly, price per litre of fuel was applied to the monetary value to get an estimation for the number of litres per fuel source and then the conversion factor was applied (see Chapter 3, Table 3.5). The findings were used in further analysis and where the vehicle was owned by the business, the emissions were attributed to a Scope 1 (see section 4.1.3, p.70).

Travel for business in vehicles not owned by the company, included air, rail and road. To ascertain baseline figures the model was configured on a set of established assumptions. Air travel data was collected by asking the businesses if they used air travel for business purposes how many domestic, short and long haul flights they made annually. The frequency of travel from their responses was modelled on distance, flight hauls for domestic, short and long, and on average passenger class and RF, conversion factors as appropriate to the haul and class was applied (see Chapter 3, Table 3.6, p. 47).

The emissions for rail travel used for business purposes was gauged by asking the recipients their most common journey by train and how many times a year they made that specific trip. The

distance for the main journey was calculated using Travelfootprint.org (Ecolane, 2007) and the conversion factor for national rail; was applied (see Chapter 3, Table 3.7: p.47).

The impact from road vehicles used in commuting by employees was captured and modelled. In this instance, the type of fuel used, quantities in either volume or estimated expenditure resulted in fuel litres and fuel conversion factors as appropriate for ‘fuels’ applied but assigned as a Scope 3 emission. The rationale for this approach, is fuel conversion factors provide more accurate emissions results (DEFRA, 2013b) and the additional assumptions that would need to be made as to the type of vehicle(s) would create greater inaccuracies and uncertainties.

4.1.2.4. Equipment

The production and manufacture of equipment was represented in the model from details supplied by the respondents who provided a description and the numbers of equipment they possessed. The variety and numbers of equipment provided was assigned into nine discrete categories (see Table 4.4) and the three most prevalent units of equipment were used in the model.

Table 4.4: Reported numbers of units of equipment

Capital items (<i>equipment</i>)	Total no. of units reported	% contribution
Printers ¹	252	21
PC (desktops) ¹	487	40
Laptops	87	7
Specialist equipment	231	19
Telephone	3	Less than 1 (0.25)
Fax machine	20	2
Photocopier	17	1
Servers	50	4
Kitchen Items	60	5
Totals	1207	100

¹ It is recognised that outliers influence the total no. of units reported however, it was decided to acknowledge them because they were actual reported observations.

The table shows for the respondents three main units of equipment reported that could be modelled. The items included desktop PCs, laptops and printers. The specialist equipment reported for instance, a baler, card-processing terminal, franking machine was too specific to enable a generic unit of equipment to be modelled that would be relevant to each business. Once generic units of equipment had been established the amount of GHG emissions for each of the units needed to be sourced. The Ecoinvent database was sourced and using the ReCiPe methodology the mid-point impact category value for climate change was used and modified to incorporate a five-year life expectancy for the equipment (see Table 4.5). The figures were applied to the unit of equipment and the total amount applied to the business was dependent upon the numbers of units they reported. The values were attributable to Scope 3 and used in further analysis (see section 4.1.3).

Table 4.5: Amount of GHG emissions used to represent the production and manufacture of equipment in the model

Equipment	kgCO ₂ e per unit (<i>ReCiPe methodology for climate change</i>)
Printer (laser jet colour)	~14
Laptop	123
PC (desktop) and accessories	~934

4.1.3. Amounts of GHG emissions

The findings showed that the service industry respondents produced on average ~ 70 tonnes of GHG emissions per year in 2011. The figure accounts for the impact of gas and electricity use, waste disposal, travel connected to the service provision and the production and manufacture of equipment. The employees produced on average 4 tonnes of GHG per year in the conducting of their service. The largest impact from the sector was from Scope 3 emissions, which contributed, to 62% of all impacts (~3,000t CO₂e), Scope 2, 4% (~180t CO₂e) and Scope 1, 34% (~1700t CO₂e). The activities considered within the scopes are represented in Figure 4.4 (see Table 3.8: p.47, for a definition and description on what scope activities entail).

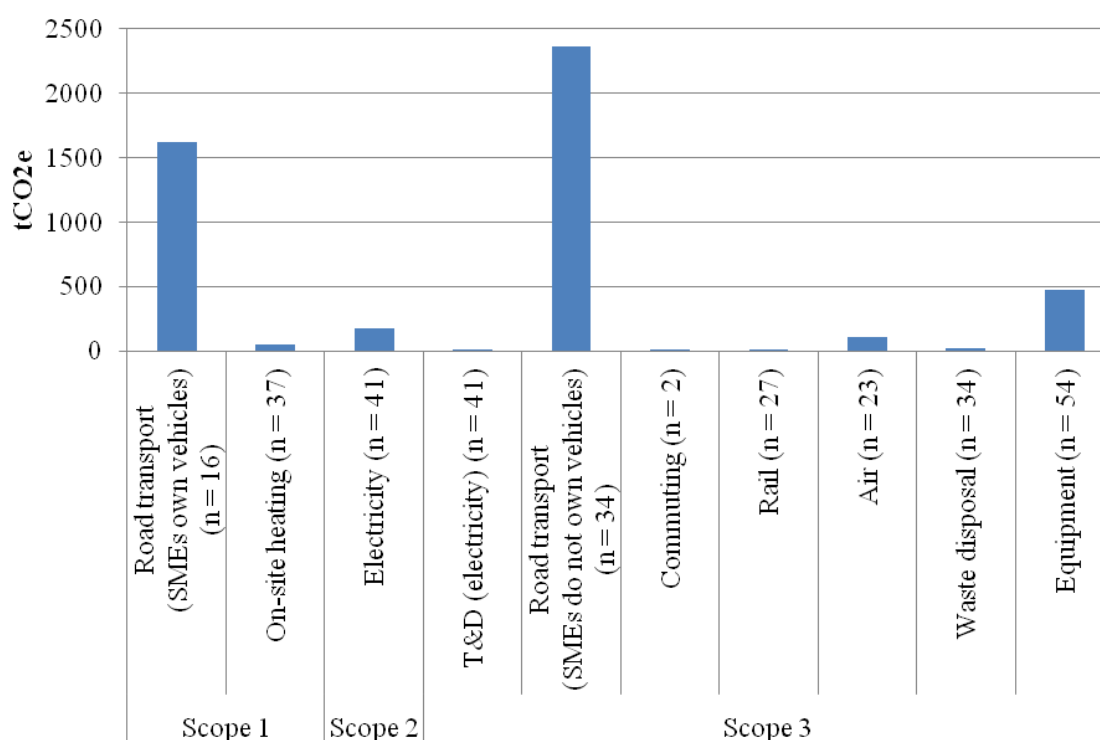


Figure 4.4: Amount of GHG emissions produced by the service industries in terms of scope and activities

Figure 4.4 shows the impacts of each component in terms of the total amount of tonnes of CO₂e produced. The impacts from the companies are focused on road transport reported to be used by fifty respondents, which contributed to ~ 34% and ~ 49% of the total emissions respectively.

4.1.3.1. GHG emissions and scale of business

To discern if there were any variations within the companies relative to the size of the business, to develop scale specific strategies for reducing GHG emissions; the following findings were determined and are presented in Table 4.6.

Table 4.6: The amounts of GHG emissions calculated in accordance with DEFRA (2013b) guidelines relative to the scale of the business

Scale of business	Average No of FTE	Average floor space m ²	kgCO ₂ e / year / business (average)	kgCO ₂ e / employee / year	kgCO ₂ e / m ²	% contribution of GHG emission per Scope		
						Scope 1	Scope 2	Scope 3
Sole (n = 10)	1 (self)	~83	~5,300	~5,300	~64	7%	34%	59%
Micro (n = 31)	4	~447	~18,000	~4,500	~40	34%	13%	53%
Small (n = 20)	20	~1,700	~77,000	~3,800	~45	31%	4%	65%
Medium (n = 8)	80	~23,600	~336,000	~4,200	~14	37%	1%	62%

In terms, of the contribution the scale of business makes to total GHG emissions; the sole business owner contributed 1%, micro, 12%, small 32% and medium 55%. To determine the significance of the scale of the business relative to the amount of GHG emissions produced a Mann Whitney U-Test was applied to data to test the independence between two independent groups (< 50 employees and > 50 employees but < 250) on a continuous measure; GHG emissions. The test revealed a significant difference in the size of a SME and the total amount of GHG emissions produced for both Scope 2 and Scope 3 emissions (see Appendix B: Table 4-5). In terms of Scope 1 emissions it was determined there was no significant difference in the total amount of emissions produced relative the scale of the business (see Appendix B: Table 4-5).

In each scale of business, Scope 3 emissions contributed to over 50% of GHG emissions and in those businesses with on average in excess of 4 FTE employees, over a third of emissions were attributable to Scope 1. The findings follow the trend of the highest production of GHG emissions being equated to low employee density hence the sole employee employing him/herself produced ~5,300kg CO₂e annually. The glitch in relation to the medium businesses can be attributed to the low sample size. In theory, the amount of GHGs produced by the medium business should be lower because they have a higher density of employees.

In terms of emissions production as a measure of a buildings efficiency and determined in kgCO₂e/m² the following method was applied. The total number of employees per scale of business was divided by the total sum of the floor area. This value was then divided into the total kgCO₂e per employee within that scale of business. The sole trader is working in or from the least

energy efficient business space. The medium business is more energy efficient and produces ~14kg CO₂e per meters squared of business space. It would be expected that the small businesses produce less kgCO₂e than the micro-businesses. The findings for the small businesses may be attributable to greater differences in the economic activities within this scale of businesses, in terms of service provision.

The substantiation of these baseline values within the literature is challenging. The values reported for GHG emissions in relation to SMEs is hindered by the use of differing methodologies as seen by CSR and company reports from websites and definitions of the term business. The use of figures provided by ERM (2010), although limited can be used as a comparative indicator to context the determined baseline values. Consequently, the range of values presented by ERM (2010) show a micro business producing 30t CO₂e, small businesses ranging from 340 to 600t CO₂e (\bar{x} = 470t CO₂e) and medium from 270 to 7,000t CO₂e (\bar{x} = 3090t CO₂e). The differences in variation of values between the literature and study figures of between four to six times greater is attributable to secondary sector businesses; for example manufacturers of steel wire, which are more energy intensive than service industry SMEs.

The average emissions value established for a service industry SME was 70t CO₂e/year. In relation to the two values presented by ERM (2010) for a service business, the average figure was ~300t CO₂e/year. The presented value is approximately four times greater than the established value. The results owing to the paucity of comparative data and uniformity in the quantification of GHG emissions among SMEs are inconclusive. The paucity of credited data and detailed work means there is a need to determine GHG emissions relative to the scale of business within service industry SMEs to establish detailed emissions values to aid reduction strategies.

The lack of data is given added emphasis when the average net GHG emissions per head of the population (capita) for England were 7.9t CO₂e in 2011 (ONS, 2012) and micro, small and medium businesses have emissions in excess of this capita level. Accordingly, the next section based on the findings established in section 4.1.3, distinguishes reduction strategies, by proposing three scenarios through which the SMEs can make financial savings and improve efficiency by addressing specific Scope 1 and Scope 3 emissions.

4.1.4. Proposition: development of three scenarios

To reduce the impacts of the service industry businesses collectively, Scope 1 and Scope 3 emissions, most notably road transport and equipment (see Figure 4.4) can be considered. To reduce the impacts three scenarios were developed and modelled. The first, scenario considered alternative fuel options travelling for one meeting for a reported distance of 372 miles or ~599km. The second scenario considered reducing the road transport in Scope 3 by 10% and replacing this

business travel by video conferencing. The third scenario considered the items of equipment used by the companies, increased the numbers of laptops by 10%, and reduced PCs by 10%, relative to the total numbers of reported computers.

4.1.4.1. Scenario 1: alternative fuels

The respondent businesses used petrol or diesel to power the vehicles they owned for business travel none used the *greener* options for instance, liquid petroleum gas (LPG), auto gas or compressed natural gas (CNG). The two fuel options can be used as a replacement for petrol or diesel and are marketed as being better for the environment because of the low carbon content and high-octane levels, which result in lower carbon emissions. The model was developed based upon the most common car in the UK, the Ford Focus (DfT, 2012) that returned an average 60mpg (WHATCAR, 2012). The conversion factor for each fuel type to kgCO₂e used DEFRA (2013b) figures. The cost of fuel per litre was as follows: diesel, £1.39, and LPG, £0.76 based upon the UK fuel price averages (AA, 2011a, b). The price of CNG was £0.80 per kg, based upon the average price in Europe (CNG Europe, 2014), and calculated for a value of 19kg /m³/l.

The findings summarised in Table 4.7 show there would be a decrease in the amount of GHGs produced travelling to a meeting using the alternative fuel options which also has sizable reductions in costs for fuel.

Table 4.7: Findings from the model by replacing diesel with alternative options relative to travelling to one business meeting

Fuels	Conversion factors*	Fuel required	kgCO ₂ e	Reduction in GHG emissions (%)	Fuel costs (£)	Cost savings on fuel (%)
Diesel fuel (<i>bench mark fuel</i>)	2.6008	27l	~70		37.53	
Compressed Natural Gas (CNG)	0.473762	19kg/m ³ /l	~13	~81	15.20	~59
Liquid Petroleum Gas (LPG)	1.4929	35l	~52	~26	26.60	~29

(* Source: DEFRA, 2013b)

Accordingly, the use of CNG to travel to a meeting results in an 81% decrease in GHG emissions and a 59% saving on the cost of fuel. The use of LPG is equally beneficial to the environment and of financial benefit to the business. The use of LPG resulted in a 26% decrease in GHG emissions and a 29% reduction in the fuel costs (see Table 4.7). The switching to these alternative fuel options would make lucrative savings for the business in terms of its '*bottom line*'. The findings however, exclude the costs of installing or converting the vehicles, ownership costs and depreciation rates. As a capital investment therefore, the business would need to assess their particular business model before making the transition to an alternative fuelled vehicle(s).

4.1.4.2. Scenario 2: video-conferencing

The literature on ICT services and business meetings and their findings are difficult to compare because the functional units vary, the allocation procedures between networks and services are not fully stipulated, and the numbers of users per video conference meetings is arbitrary (Finkbeiner, 2011). The grey literature is equally reticent in terms of transparency and arbitrary data. Subsequently, there is no standardised method that can be used to represent the use per year of typical ICT services to typify business meetings undertaken using video conferencing as an option (Finkbeiner, 2011).

The model was based upon data collected from the businesses reported for emissions attributed to Scope 3 road transport. To this collected data from the businesses, the following assumptions were utilised to develop the model:

- The number of business meetings that produced the GHG emissions was assumed to be 345 per year. This figure was based on the association meetings market, which detailed the numbers of meetings held in the UK in 2009 (ICCA, 2010)
- 59% of the meetings attributed to Scope 3 road travel based upon respondents reported fuel consumption
- 20 meetings to be held via video-conferencing
- Total kgCO_{2e} for one video-conferencing meeting per hour inclusive of the production of the equipment for the meeting and the ICT equipment used 7.5kg CO_{2e} (Finkbeiner, 2011)
- To conduct 10% of meetings via video-conferencing; is $20 \times 7.5\text{kg CO}_2\text{e} = \sim 150\text{kg CO}_2\text{e}$
- The avoided travel $372\text{ miles} \times 20 = 7440\text{ miles}$
- Price of the dominant fuel used by respondents, £1.39 for a litre of diesel
- Based on a Ford Focus vehicle with an average of 12 miles per litre
- Emissions factor for the dominant fuel used diesel (2.6008) this equates to $\sim 1612\text{kg CO}_2\text{e}$ in avoided GHG emissions
- Model excludes licence, subscription and maintenance fees in the costs that can be saved

The findings (see Table 4.8) show conducting 10% of meetings by video-conferencing would result in a $\sim 91\%$ decrease in GHG emissions from avoided travel. In terms of the costs, annual avoided travel would result in annual savings of $\sim £862$ in fuel. The use of video-conferencing should be considered a viable option for service industry businesses in abide to reduce their costs and GHG emissions. The potential to save £862 in avoided costs for fuel per year means that businesses could install the lower priced conferencing facilities, which will take less than a year to re-coup the investment.

Table 4.8: Findings from the model replacing 10% of meetings with video-conferencing

Mode of meeting	kgCO ₂ e per mode	Reduction in GHG emissions (%)	Annual avoided cost for travel (£)
Face-to-Face (avoided travel to meetings)	~1612	~ 91	~862
Video-conferencing	~150		

The option is only viable if the recipient business is equally equipped with the appropriate facilities. The type of video-conferencing facility depends upon a number of factors most notably for SMEs the budget, usage, preference (*desktop versus room video conferencing*), site function and how the business plans to use the system. Investment in video-conferencing facilities and the payback on investments will need to be made individually by businesses in the light of such factors and within the context of the purpose for meetings (Avexia, 2012).

4.1.4.3. Scenario 3: equipment

The equipment was highlighted as a potential area in the reduction of GHG emissions within the businesses. The area of potential improvement was considered to be the paucity of laptop use. The findings show that 40% of the sector is likely to use a desk-top PC as their main piece of office equipment as opposed to a laptop which was used by only 7% of the businesses. Further findings has shown that based on a life expectancy of five years laptop produce on average 123kg CO₂e/unit and desk-top PCs and their accessories ~934kg CO₂e (see Table 4.5). A model was developed which increased the use of laptops by 10%, decreasing the use of desktop PCs relative to the total number of reported items of computer equipment. The findings show there was a reduction in emissions by ~10%, from 469,891kgCO₂e to 423,664kgCO₂e from the production and manufacture of the equipment by applying this scenario to the equipment category in Scope 3. The individual SMEs where it is feasible therefore, needs to consider using laptops as opposed to desktop PCs when they are replacing their equipment.

The application of Scenarios 2 and 3; the former using video-conferencing to conduct 10% of meetings and the latter, replacing PCs with laptops has the potential to decrease GHG emissions within Scope 3. The adoption of these options has the potential to benefit the business individually, the environment and the government in its 2020 reduction targets.

4.2. Qualitative analysis: roundtable discussion results

The findings from seven employees who participated in the roundtable discussion are organised into a narrative summary with descriptions and representative data illustrations as appropriate (see Appendix B: Table 4-6: profile of participants). The narrative is discussed within the context of the SME environment from topic headings facilitated through researcher-guided questions.

4.2.1. Government policy and funding

The roundtable discussion highlighted the continual changes that employees had to contend with in relation to the government's policy towards the GHG agenda. The participants wanted the government to take a stronger lead with SMEs by offering direction, consistent support and guidance for them to minimise their GHG emissions. The participants felt at present, specific programmes for their needs, '*...flickered in and out of existence like sub atomic particles...*' (Participant #1) and information by differing agencies on minimising GHG emissions was fragmented and left them confused. They agreed that a '*one-stop shop*' that offered a central advice '*hub*' should be established to counteract the misinformation they were receiving. Presently, their interaction with government-backed schemes for the majority of participants had left them feeling disheartened, cynical, and distrustful of government programmes.

The discussion on government funding and spending brought to the fore two distinct sets; those who felt the SMEs should self-fund their environmental programmes and those who believed the government should offer funded and subsidised schemes. The self-funding set felt that government funded programmes encouraged SMEs to take grants for the period of the programme and '*...pay lip service...*' (Participant #4) to the initiative as they have not invested anything tangible into the programme. The advocates of public funding initiatives felt that the lack of consistent government funding programmes; produced an *ad hoc* approach to minimising GHG emissions, which counteracted the initial enthusiasm.

The belief among the participants was that if the government was going to fund environmental initiatives these would have to be consistent. The inconsistent government funding however, led to views being expressed that a more independent and less bureaucratic form of funding or options needed to be explored for instance, internal sector programmes. Consensus within the discussion was that the majority of participants however, would value the government offering a well thought through longer term funding package to assist with the implementation of GHG reduction initiatives.

4.2.2. Green terminology

To engage with a target audience it is necessary to use terminology that has the ability to attract interest or gain attention. The literature on SMEs acknowledges that it is difficult to connect with these businesses to reduce their environmental impacts (Hillary, 2000). The participants' views and opinions on a number of environmental terms was presented for debate. The results showed (see Figure 4.5) from the presented terminology the participants felt carbon footprint was the most successful ('HIT') term in engaging their companies.

The participants valued the term carbon footprint because functionally it can be used as a '*tool*' to quantify and compare their carbon emissions and in some cases, their customers had requested it; which gave the term added significance. The participants preferred the term '*footprint*' because it was tangible; familiar and perceived as easily understood. The belief among the participants was that the term makes a connection both on an individual and public level. The response in the literature to the term carbon footprint however, is dependent upon whether the findings are interpreted from a populist or academic research perspective. In the populist media where the term is widely used by government and business, the views of the participants are confirmed (Finkbeiner, 2009; Pandey, Agrawal & Pandey, 2011).

In the research and academic communities however, the literature on the term carbon footprint, is not as enthusiastic. In academia, the term has no clear definition and there is confusion as to what the unit actually means and measures (Weidmann & Minx, 2007; Finkbeiner, 2009). It is appreciated that within academia, the public perception of the term lacks rigour however; this should not be seen as major flaw because *familiarity* with the term is a positive in relation to communicating and engaging with SMEs.

The three terms that failed to attract interest or gain attention ['MISS'] were carbon neutral, greenhouse gases (GHG) and sustainability. The participants felt that the term carbon neutral failed because it was a fashionable and vague concept whose reputation had been besmirched by large organisations '*buying-off*' their emissions. Greenhouse gases was also a 'MISS' because it was considered to be '*unproductive*'. The participants felt the term was confusing and endorsed a feeling of helplessness because of its global connotations, contributing to its failure. The consensus among the participants was that the term invoked; an international global problem, which was not current or relevant to their local communities.

Sustainability was a 'MISS' because they felt it was a vague term where its application to SMEs could not be easily recognised. The belief among the participants was the lack of explicit relevance to SMEs impaired the term's ability to connect with smaller business. The majority of participants greeted the phrase green economy with ambivalence and they were 'UNDECIDED' whether the term was a 'HIT' or 'MISS'. The participants felt that the term was ambiguous and was not relevant to SMEs. The consensus was that the term is a piece of '*top-down*' political jargon that has no relevance within the business sphere.

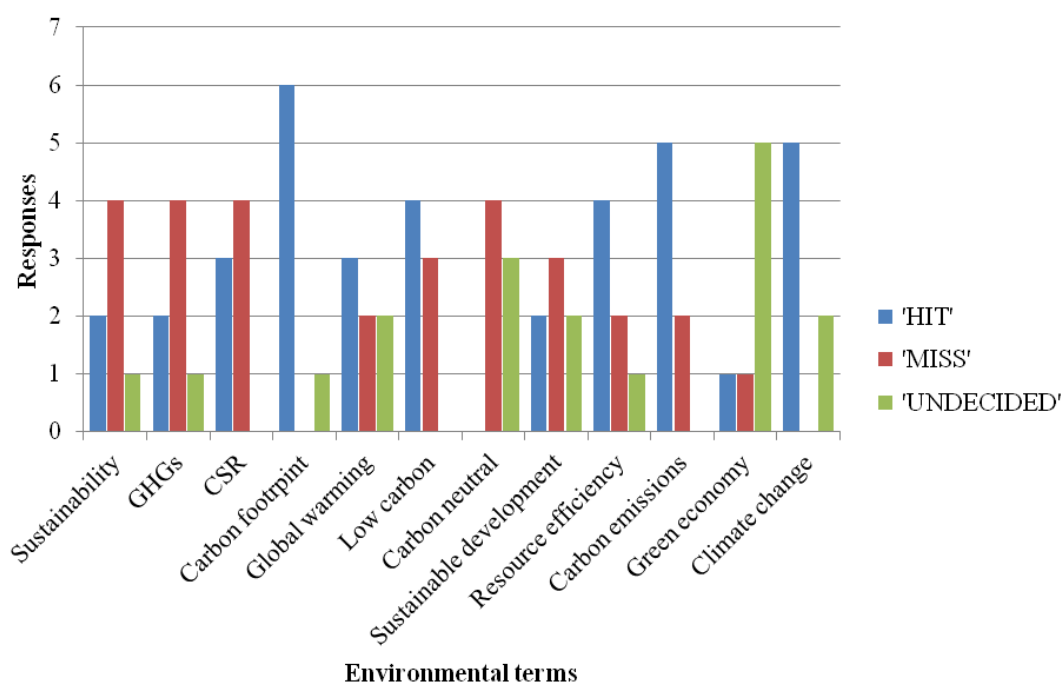


Figure 4.5: Responses from employees to the relevance of environmental terms

4.2.3. Barriers experienced by employees

The literature was used to identify ten generic barriers that encompassed internal and external obstacles that were deemed to contribute to environmental inaction among SMEs (Bianchi & Noci, 1998; Vos, 1998; Tilley, 1999a, Petts, 2000; Schaper, 2002; Masurel, 2007; Revell, Stokes & Chen, 2010; Cohen, 2013).

The ten barriers were presented to the participants for discussion. The majority of participants either felt strongly or agreed that the main barrier they would face managing GHG emissions was the competing priorities that resulted from working in a small business (see Figure 4.6). This barrier encompasses the tasks and activities involved in working in a SME for instance, customer services, and fulfilling orders, which competes for resources and time. The participants were of the view that these factors worked to consign minimising GHGs low on their list of priorities.

The synergistic nature of the roundtable discussion and use of probe questioning resulted in the discussion gravitating towards the barrier; lack of skills or expertise. The participants felt that they lacked the skill set needed to undertake monitoring and measuring their carbon emissions. The participants were of the belief that their lack of skills was jeopardising the progress of minimising GHGs. The participants proffered that as a long-term objective; the techniques for measuring, managing, and eventual reporting of emissions needed to be incorporated into management courses and *'every business course going...'* (Participant #3).

Employees highlighted lack of skill and expertise as a main barrier hindering the progress of minimising GHGs. The general environmental literature corroborates this finding and cites this barrier as one to explain the lack of environmental improvements undertaken by SMEs (Walker, B., *et al.*, 2008; Borga, F., *et al.*, 2009; Brammer, Hoejmosse & Marchant, 2012). In addition, the literature suggests the focus needs to be on information and education initiatives that will help SMEs become 'eco-literate' and raise the awareness of environmental impacts they create (Clark, 2000; Hunt, 2000; Tunnessen, 2000; Fanshawe, 2000; Tilley, Hooper & Walley, 2003). This is of importance because when employees and the employers are aware of environmental issues they are able to pursue environmental activity at a higher level (Brio & Junquera, 2002). This action would prompt the need to standardise information and by up-skilling, potential employees give them the confidence to undertake more environmentally technical activities.

The consensus among the participants was that the three notable obstacles to them minimising their emissions were competing priorities, lack of skills and expertise, and the difficulties of getting culture and behaviour to change.

4.2.4. Mechanisms, guidelines and procedures

The premise for this part of the discussion arose from the current literature which states that SMEs cannot be expected to take an active interest in the environment unless it is made mandatory (Studer *et al.* 2008). The views and opinions connected to adopting mandatory reporting to minimise GHG emissions and the potential '*tools and rules*' that could be used by SMEs was explored.

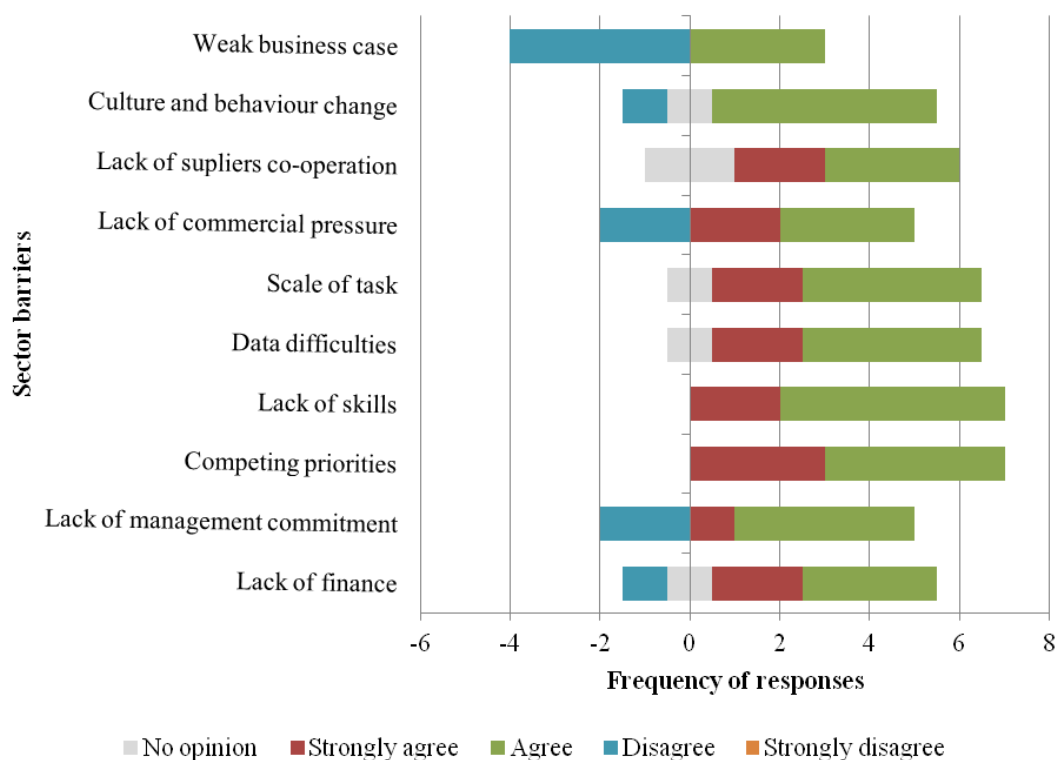


Figure 4.6: Responses from employees to the main barriers that hinder the minimising of GHG emissions

4.2.4.1. Employees and mandatory reporting

The views of service industry employees to the mandatory reporting of GHG emissions is unknown however, there is acceptance they would be antagonistic to this approach. To gauge how willing or unwilling the participants were to contemplate the mandatory measuring and reporting of their carbon emissions; the participants responses were coded using ‘RECEP’ (receptive) and ‘UNREC’ (unreceptive), in the discussion on reporting.

The receptive set valued and recognised the benefits of mandatory reporting as promoting greater accountability and transparency in controlling carbon emissions. The appeal towards a mandatory approach was enhanced as they felt it would address internal power struggles within departments and conflicts that can arise from shared occupancy units with proprietors and other tenants. The following comment illustrates the receptive view:

‘...people in accounts have some of the information they don’t want to just let it out to people in erm the operational side because actually that’s their information, ... so you get this kind of internal strife ...so ...if it’s mandatory they have to do it, and so there is part of you that says oh yes that’s actually quite a good idea,...’ [Participant #5]

The unreceptive set did not value the suggestion of a mandatory approach. The views of this group were entrenched and they felt the proposition would restrict them by what they perceived as a

European *diktat*. The consensus among the majority of participants was that in theory they were amenable to the suggestion of the mandatory reporting of GHG emissions. The introduction of this approach they felt would create a ‘*level playing field*’ that would not penalise those SMEs who had invested in minimising their GHG emissions.

The participants were receptive to the idea of a mandatory approach, unlike the owner-managers who did not favour the proposal because of perceived cost of maintaining and implementing the system and lack of specialist staff (see Appendix C) however; this is a controversial issue. The literature is divided between advocates of the Porter hypothesis (1995) and ‘Pollution Haven’ hypothesis (Brock & Taylor, 2005). Presently, classification used to delineate SMEs from larger enterprises coupled with UK policy and legislative frameworks do not directly target SMEs (Vickers *et al.*, 2009; BIS, 2010b). Subsequently, nothing encourages SMEs directly to reduce and report their carbon emissions.

The mechanisms used to engage SMEs are primarily from indirect effects for instance, financial in the form of taxes, grants and loan guarantees (CCL); or ‘*soft measures*’ that are non-financial for instance, SMEs networks that enables comparison of performance with peer enterprises (NERA, 2006). The policy instruments used to achieve the objective of the mandatory reporting of carbon emissions can fall into four categories; financial or trading mechanisms; soft measures or direct regulations (NERA, 2006; BIS, 2010b). The instruments can be broadly placed into two main approaches; mandatory or voluntary.

The literature confers that regulating SMEs reduces ‘*embedded*’ GHG emissions (Vickers *et al.*, 2009); improves the environment (Gunningham & Sinclair, 2002; Revell, 2003a; Revell, 2008) and is the preferred option of smaller SMEs as it promotes a ‘*level playing field*’ (Mir, 2008). The promotion of a mandatory framework would focus attention on developing a unified approach and model Standard thereby addressing the operational, procedural and technical difficulties highlighted by the employees during the roundtable discussion (see Table 4.9).

Table 4.9: Operational, technological, and procedural difficulties highlighted by the employees during the roundtable discussion

Operational	Technical	Procedural
<ul style="list-style-type: none"> Initially need a government-led and funded initiative; Need support from industrial sectors Need support from small business organisations On-stop web site or information ‘hub’ 	<ul style="list-style-type: none"> Need metrics to be standardised Need to consider and acknowledge other environmental impacts which are not carbon intensive 	<ul style="list-style-type: none"> Need an agreed carbon standard setting out the principles and modus operandi of the system Need a prescriptive reporting mechanisms

The disadvantages to mandatory regulation for SMEs posited in the literature concerns higher costs (Sullivan, 2008; Suchard, Sapru & Stewart, 2007); harmed productivity, competitiveness (Brock & Taylor, 2005); and profits (Palmer & van der Vorst, 1996; Gabel & Sinclair-Designe, 2001); policy spill-over (Sgaard & Madsen, 2007) and the encouragement of '*end-of-pipe*' reactive measures that achieve minimal compliance (Revell, 2008; Revell, Stokes & Chen, 2010). The disadvantages are of concern but need to be substantiated with further empirical research on the effects on productivity, competitiveness, and costs to a SME.

4.2.4.2. Employees and 'tools'

The discussion gravitated towards the '*tools*' needed by SMEs in the event of mandatory reporting. The debate focused on the following:

- a) the potential support that would be needed by the businesses and
- b) the existing familiar schemes and systems that can be utilised to measure and manage GHG emissions

a) Support

Discussion on the support needed concentrated on two main areas; bespoke on-site and SME networks. The participants placed importance on the need for consistent government programmes that offered bespoke on-site individual support. The participants were of the opinion that tailored '*handholding*' would be of benefit in the formative stages of implementing reporting. The participants felt that the tailored approach and feedback on their activity would provide them with intelligent information. The consensus feeling among the participants was that the tailored approach would empower them with the confidence to embark on their own data collection and monitoring and measuring regimes in the most time effective manner.

Belief among the participants was that although this is an initially expensive process it would in the long-term save government and businesses money and contribute to the overall reduction in GHG emissions. The participants recognised that one of the main disadvantages with individual on-site support is that it is resource intensive and expensive. Another support mechanism therefore, proffered by the moderator for discussion was the use of SME networks.

Participants were of the opinion that the value of this mechanism is from its peer-learning dynamic and as a '*one-to-many*' approach, it is less resource intensive therefore, more cost effective. The participants felt this type of forum allowed them to interact with like-minded individuals, who can assist in the problem solving process as opposed to utilising the services of an expert or specialist. The participants believed this mode of learning would provide solutions that could be applied rapidly thereby reducing time and frustration from the initial problem to getting a solution. The

consensus view amongst the participants is that SME networks provided a start for businesses to engage with others and learn from them.

The initial enthusiasm for SME networks however, was mooted with a note of caution. Participants were of the opinion that the network forum was more suited to businesses located on trading estates or business parks '*hubs*'. The participants felt that at these locations, events can be easily co-ordinated; publicised, and the venue located in situ thereby countering potential commitment and attendance issues. The consensus among the participants was for those businesses that were not located within or on a '*hub*'; the preference would be for the bespoke on-site support.

b) Existing schemes and systems

The discussion moved towards existing tools that were familiar and could be potentially modified to accommodate minimising specifically GHG emissions. One of the benefits of an EMS is the improvement of business efficiency by reducing waste, the consumption of resources and operating costs (Delmas & Montiel, 2009). The majority of participants were familiar with the ISO 14001 but not with BS8555 designed specifically for SMEs. The participants who were familiar with the ISO 14001 were of the opinion and agreed that in the interim the established EMS structure could be enriched by including carbon aspect registers within the management system. The participants felt that the incorporation of a register would add breadth and richness to an established procedure and existing EMSs could be modified to accommodate the measuring and managing of GHG emissions.

Literature on this proposal and the effectiveness of this strategy is sparse however; using data collated from the IEMA Acorn Scheme for BS8555 (2003), developed for SMEs, the effectiveness of EMSs was assessed. The assessment was undertaken by ascertaining the number of system registrations; considering the operational registrations; the stage at which an EMS was registered; differences in section and regional penetration, its popularity and current trend.

The majority of the participants were not aware of the BS8555 6-phase modular programme, which enables a SME to develop a generic environmental system that can be utilised to achieve ISO14001 or EMAS. UKAS and accredited Acorn Inspection Bodies provide recognition that the SME has met the requirements of a particular phase and continue to improve their environmental performance. A successful inspection enables SMEs to join a central register, which can assist with the promotion of their environmental credentials and sourcing suppliers.

The findings for registration per sector showed that service SMEs comprised of 74% of all registrations, the primary sector, 7% and secondary sector 19% respectively. The figures give the impression that EMSs within service industries are popular and widespread however, on a closer

inspection sections are not as committed (see Figure 4.7). The professional, scientific and technical activities favoured registration and constituted ~34% of total registrations. The results are confirmed in the literature, which notes that these schemes attract a limited number of companies, and the majority were those offering environmental products and services (Studer *et al.*, 2008). The lack of section penetration indicates that an EMS would not be an effective ‘tool’ in managing GHG emissions.

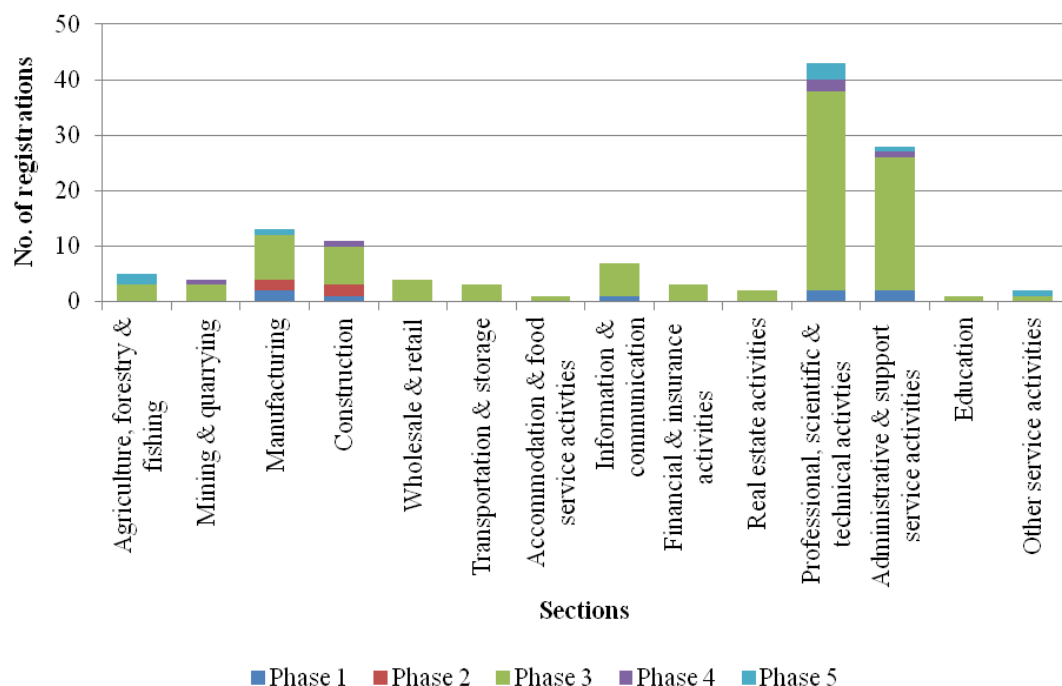


Figure 4.7: Sections: numbers of SMEs registered for each BS8555 phase (March 2010)

The breakdown of the data into regions of England showed that 25% of SMEs on the register were located in Greater London with only 12% of registrations coming from SMEs in the South West (See Figure 4.8). The regional penetration differences shows registration is not consistent thereby undermining the effectiveness of the EMS ‘tool’ as an instrument to manage GHG emissions.

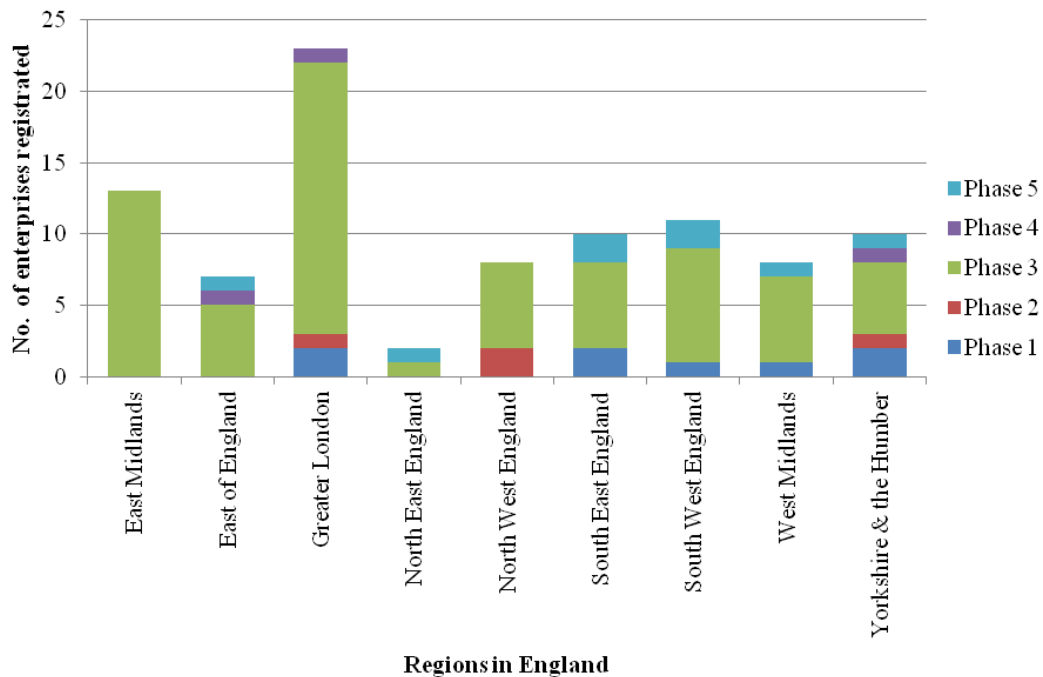


Figure 4.8: Regions: numbers of SMEs registered for each BS8555 phase (March 2010)

The findings for the number of registrations per phase, show operationally the status of the SMEs involvement with the system, found ~90% were registered between phases 1 to 3 (see Figure 4.9). Phase 1 involved committing to the scheme and setting a baseline; phase 2, recognising, and ensuring legal obligations are undertaken and phase 3, developing programmes with targets and objectives. It appears operationally that an EMS would be an effective ‘tool’ at measuring and managing GHG emissions. However, it is only phases 4 and 5 where implementation and operation and checking, auditing and management review is undertaken, that are the prominent operational stages of the EMS. In these phases, only 10% were at this level and none had attained phase 6 an acknowledgement of an EMS under ISO14001 or EMAS.

The suggestion to modify the EMS to cater for GHGs would have a limited effect on minimising emissions. The majority of SMEs are not at those stages in their EMS; specifically phases 4 and 5 (see Figure 4.9) where minimising strategies were operational. A further flaw with the incorporation of measuring and managing GHG emissions into an EMS is the systems lack of popularity and the current trend. The number of SMEs with EMSs is difficult to estimate because of the paucity of published data. However, Hillary & Burr (2011) in their study on the benefits of EMSs for SMEs determined that only 5,699 organisations had a certified management system in 2009. This is a paltry number when considering the 2009 figure of 4.4 million SMEs in the UK (BIS, 2014).

In addition, the current trend is a gradual decline in the numbers of SMEs implementing an EMS. The SME-nvironment review showed that of the businesses surveyed in 2007 (NetRegs, 2007a),

12% had an EMS however, in 2009 of those businesses surveyed only 9% (NetRegs, 2009a) had implemented an EMS showing a decrease of 3%. One reason for the decline may be the voluntary nature of an EMS. The literature shows that voluntary initiatives are ineffective with SMEs, which may explain their patchy and low take up rate (Hillary, 2004; Lawrence *et al.*, 2006).

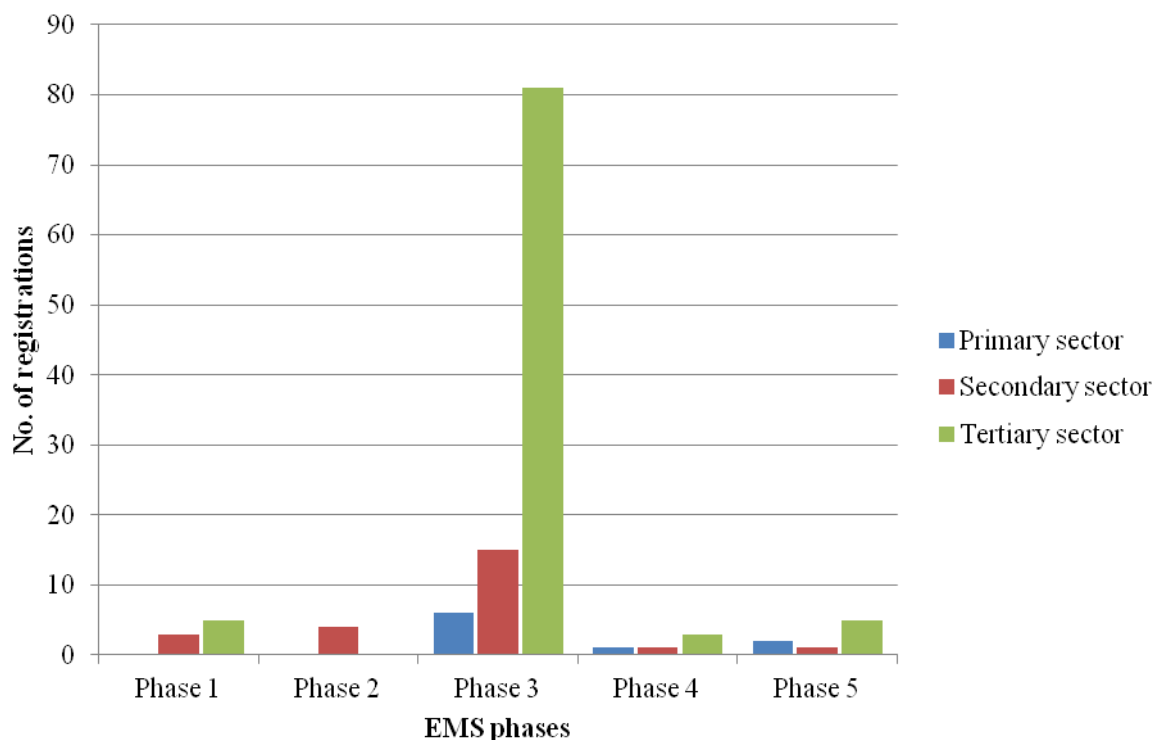


Figure 4.9: Sectors: numbers of SMEs registered for each BS8555 phase (March 2010)

4.2.4.3. Employees and ‘rules’

The discussion debated the principles that could be potentially used to govern and action the mandatory reporting within the sector; this comprised of the following:

- a) the use of existing frameworks and protocols
- b) metrics of choice used to quantify emissions and
- c) government small business guides

a) Existing protocols and frameworks

Protocols and frameworks recognised for supporting the management and reporting of emissions are the Greenhouse Gas (GHG) Protocol (WRI, 2004) and the ISO 14000 series of standards. The protocol divides emission sources into Scopes; 1, 2 and 3 respectively and were developed to improve transparency and introduce uniformity into the reporting and accounting process (see Chapter 3, Table 3.8: p.47). The Scopes were used to guide the range of emission data sources and to ascertain the degree of difficulty participants may have in collating emission information.

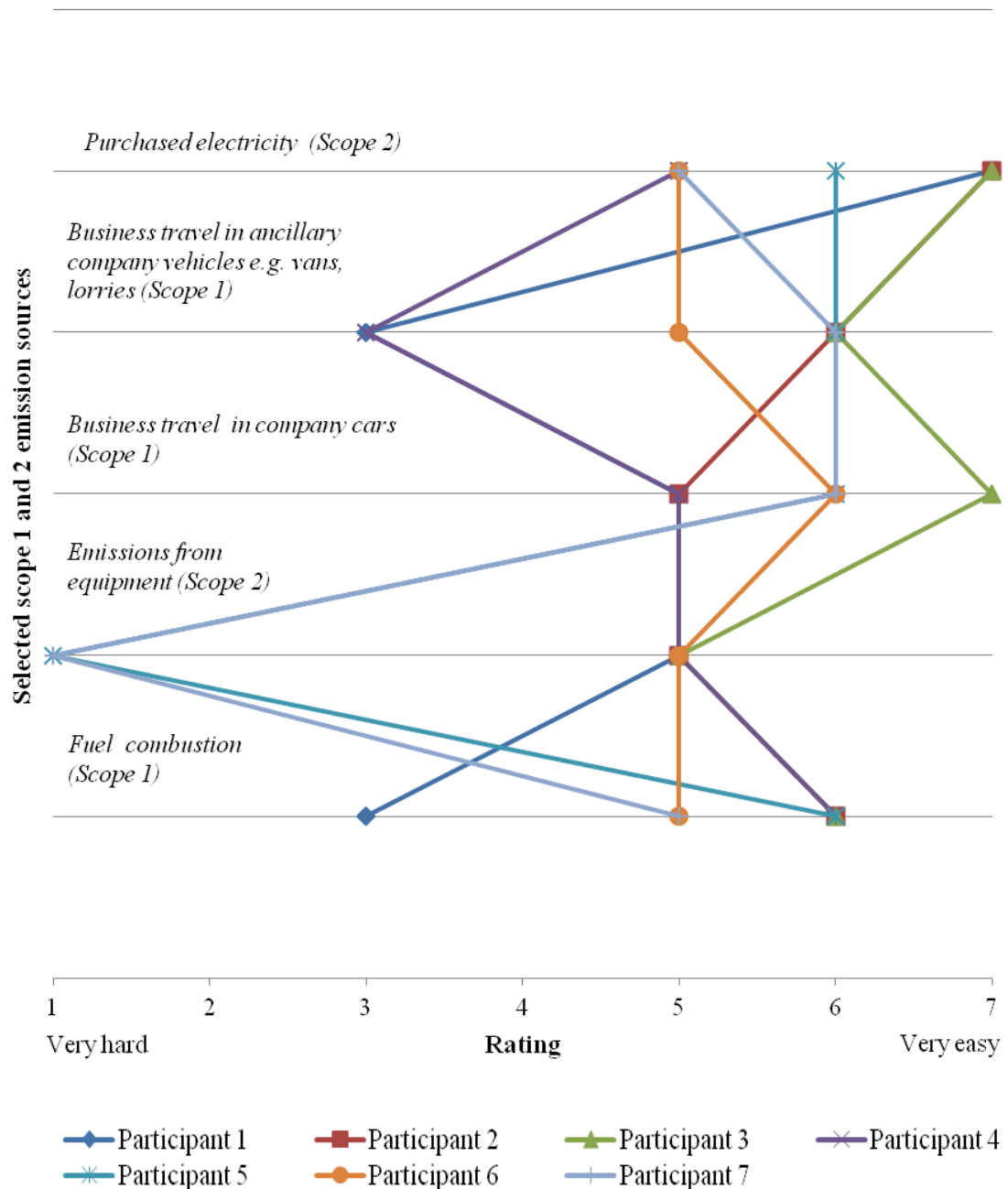


Figure 4.10: Responses from employees to the ease at which they can obtain data for selected Scope 1 and 2 emission sources

To rate the emission sources a seven point semantic differential scale was used that ranged from 1, very hard to obtain data, 4, neither very easy nor very hard to 7, very easy to obtain the information. The responses from the participants to selected Scope 1 and 2 emission sources are represented in Figure 4.10, which focused upon emissions, resulting from sources that the business either controls or owns, and Scope 2 emissions, generated from electricity purchased by the business. The responses by the participants to the selected Scopes accorded within the easy spectrum (see Appendix B: Table 4-7). Subsequently, collating data and information for the selected emission sources Scope 1 and 2 received a positive endorsement by the employees. All of the participants considered it quite easy (5) to very easy (7) to obtain and access information and data for business travel in vehicles owned by the company and for purchased electricity.

In Figure 4.11, the results of the participants' responses to the accessibility of Scope 3 data for selected emission sources are illustrated. The results for selected Scope 3 emissions show that the participants would find it increasingly harder to obtain the necessary emission data, which resulted from activities as a consequence of the business but resulted from sources owned or controlled by other organisations (see Appendix B: Table 4-8). Data and information for the selected emissions for this Scope was within the hard spectrum and therefore, received a negative endorsement by the employees.

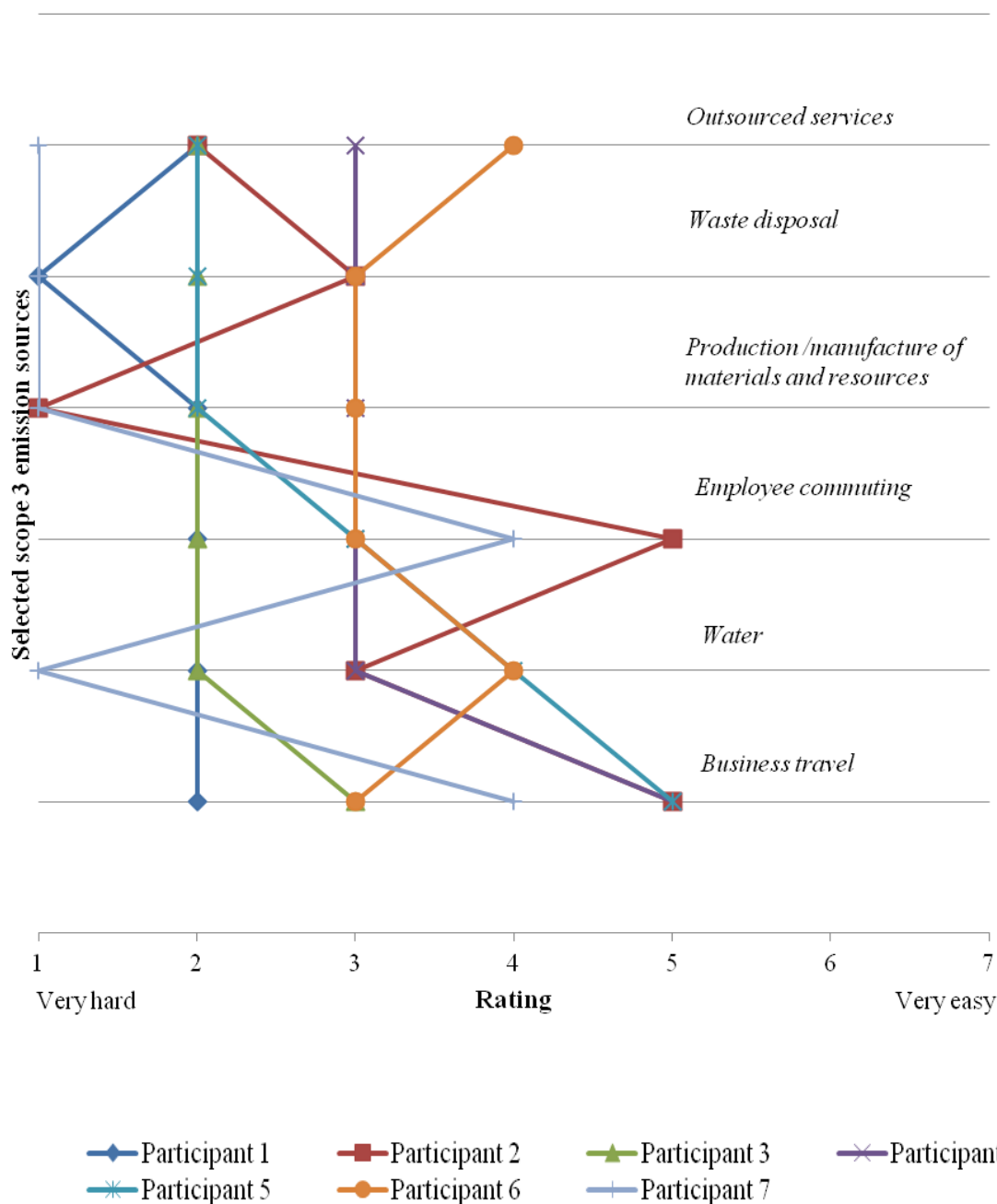


Figure 4.11: Responses from employees to the ease at which they can obtain data for selected Scope 3 emission sources

The majority of participants felt that emission data from the production and manufacture of materials and resources used by their businesses would be the hardest to collate. The participants did not consider all Scope 3 emissions data beyond their capabilities and hard to collect; for instance, emission data for business travel in non-business owned vehicles for instance, trains or rental cars were quite easy to collate.

Two distinct sets were observed during this discussion, those participants who were conversant with Scopes 1, 2 and 3 and those who were unfamiliar. The majority of respondents however, were unfamiliar with the terms. The perspectives for those who were unfamiliar with the Scopes and those conversant understandably differed. The unfamiliar set felt initial shock at a potential task of using Scopes and considered them complicated.

The participants that were conversant with the Scopes highlighted the practical concerns they had with the approach. The two main areas of concern were; data, and the technical difficulties with operational and system boundaries. In relation to the data concerns, the lack of a standardised metric they felt undermined the reliability and quality of emission level measurements.

The participants were of the opinion that Scope 3 obligations for GHG emission this would be too challenging, because of the lack of infrastructure and support along the supply chain. In addition, they felt Scope 3 was too complicated, and accessing the data would not be feasible, especially as multi-nationals were struggling, as illustrated by the following comment:

‘...it is incredibly complicated, and I know somebody who’s doing that for Tesco’s, he left the job. He had to go through everything they sold, it gets hideously complicated very quickly...’
[Participant #1]

The results show that the participants could in theory monitor, measure, and account for Scopes 1, and 2. Literature on the feasibility of the service industry employees measuring Scope 1 and 2 data is sparse however, anecdotally:

‘..they’ve got a lot of SMEs who’ve done very well on measuring and managing the Scope 1 and 2s...’ [Participant #2]

b) Metrics of choice

In the discussion, the lack of a standardised metric was debated. The assumption was that the measure would be carbon and carbon dioxide equivalents to accommodate greenhouse gases. The use of CO₂e as a quantifying measure appealed to participants who were familiar with the term. Participants during the discussion and upon further questioning however expressed concerns that

CO₂e would be the sole and standard measure of choice. The participants felt focusing upon carbon, ignored biodiversity, land issues, low carbon impacts for instance water and resource inefficiency generally and only highlighted perceived high carbon emissions, was misleading, as the measure loses the wider impacts detail. The following series of comments expressed the intensity of concerned feelings:

'..I just get very concerned about it becoming the standard of choice, the measure of choice, I think it is part of the measures but I get very nervous ...' [Participant #2]

'...to use a CO₂ equivalent as a measure of the whole picture is extremely dangerous...'
[Participant #4]

c) Small business guide(s)

One set of 'rules' provided by the government department DEFRA in response to the Climate Change Act 2009 was the *Small Business User Guide* (DEFRA, 2009). The guide outlined how SMEs can measure and report their GHG emissions and proposed seven steps to assist implementation. Step 1 identifies and outlines parts of the business that needs to be included in the measuring and reporting of a process; and step 2 how to identify the activities in the business that relate to GHGs. Steps 3 and 4 present the metrics, how to collect and convert data. Step 5 considered strategies on how to identify ways to reduce emissions; step 6: demonstrated how to continue monitoring the emissions and step 7, how to report emissions.

The majority of the sector representatives were not aware of the guide and the participants who had a perfunctory recognition of the publication had no incentive to adopt the approach and believed it was not applicable to their needs.

4.2.5. Drivers experienced by employees

A list of generic drivers sourced from the literature was presented to the roundtable for discussion (Baylis, Connell & Flynn, 1998; Merritt, 1998; Verheul, 1999; Tilley, 1999a; Hillary, 2000; Revell & Blackburn, 2007; Walker, Redmond, Sheridan, *et al.*, 2008; Revell, Stokes & Chen, 2010). The drivers presented for discussion fell into five categories. The categories were regulatory, monetary (*savings and gaining contracts*); supply chain requirements; professional reputation and new technology. The weight of interest these drivers presented was evaluated using the amount of time they spent discussing the drivers (see Table 4.11).

Table 4.11: Interest expressed by employees to presented drivers quantified by the time spent in seconds discussing the issue

Drivers	Time (s)	Time (s) (%)
Regulatory	89	20
Monetary	55	12
Professional reputation	65	15
Supply chains requirements	164	37
New technology	71	16
Totals	444	100

The participants identified the requirements and demands made by the supply chain as the main driver. On occasion, they had felt coerced by their supply chain to agree to their stipulations or lose the contracts. The participants who had undertaken these supply chain enhancements had not yet realised the long-term benefits of cost reduction, operational efficiency, and enhanced customer values; factors that are reflected in the literature (BSR 2001; Drake, Purvis & Hunt, 2004; Darnall, Henriques & Sadorsky, 2008; Walker, Sisto & McBain, 2008).

The employees felt that the larger organisations were equally confused about their obligations, were too powerful in comparison and their competences and judgements too automatically trusted by government agencies. The participants felt there were external forces driving the suppliers themselves, which was skewing the broader sustainability agenda. The following comment illustrates this view:

‘[It] comes in, the scary thing about that is that it is very bursty, it comes in very suddenly.’
(Participant #1)

There was a belief among the participants as actors within their supply chains that they were pressurised to conform regardless of the operational difficulties this created. The participants’ felt the supply chain was dictating to them how the business should be run; which their employers did not welcome.

The supply chain and the actors conduct are pertinent for service industry businesses success in being accountable towards the environment. The academic literature and the studies on the influence of the supply chain and SMEs are inconsistent. Some studies show that the supply chain is not a main driver and has little impact on SMEs behaviour (Merritt, 1998; Preuss, 2001). Other research studies show that the supply chain is an effective mechanism and driver for SMEs to undertake environmental activities and getting changes (Lamming & Hampson, 1996; BSR, 2001; Studer *et. al.*, 2008). The discrepancies between the conclusions in the literature and this roundtable discussion can be potentially attributed to the sector, the location of the SME, the globalisation of their supply chain and the sampled population.

The majority of participants saw regulation as a driver that would encourage them to measure and manage their GHG emissions; two distinct sets however, emerged. The sets were classified under the idioms '*carrot*' and '*stick*'. The '*carrot*' set favoured the highlighting of rewards and the '*stick*' set punishment to induce SMEs to minimise their GHG emissions. Participants in the '*carrot*' set expressed the views that no legislation would be needed if the minimising of emissions were shown to reduce SME's expenditure.

Participants however, in the emergent '*stick*' set expressed the views that to encourage SMEs to minimise GHGs, a historical perspective needed to be taken and correlated to the development of health and safety. The majority of participants, however, expressed the belief that to ensure service industry businesses participated in the move towards a low carbon nation the '*stick*' approach needed to be emphasised more. The participants felt that a *laissez-faire* approach by SMEs had resulted in a lack of progress in minimising GHG emissions.

The participants expressed the view that SMART technology has a limited influence on business activity. The discussion revealed that the participants were unaware of resource efficiency technologies that could be of benefit, reduce carbon emissions and produce financial savings. Probe questioning revealed amongst the participants a perception that these technologies were confusing, complicated and subsequently, difficult to understand. The participants expressed an underlying fear that concerned the authenticity of the SMART technology. The lack of awareness, validation, and promotion of these types of innovations prevented them from being currently utilised. However, the participants felt technology had the potential to be an effective driver if there was greater product awareness and accessibility.

Technology, according to the literature, can affect a service in terms of the rate of change it can bring to production practices and from the introduction of innovative products (Brio & Junquera, 2002). Business can be affected from resulting purchases, installing and maintenance costs although, benefits can potentially accrue from greater efficiency. Generally, in the literature, new technology is expressed as a relevant driver that assists SMEs in the minimisation of their emissions (Hillary, 2000). The argument expressed is that the expansion of SMART carbon abatement technologies would enable businesses to reduce their emissions more effectively, for instance energy usage, by the use of smart metering.

4.2.6. Benefits of reporting to employees

The obstacle that blocks reporting by SMEs is they do not believe this activity can benefit their businesses (Cohen, 2013). To encourage SMEs to minimise their emissions and eventually report levels the participants debated their views and opinions on the values and benefits of reporting. The responses from the participants to a list of values and benefits adapted from the perceived

values and benefits gained from environmental practices identified in the literature (Banerjee, Iyer & Kasyap, 2003; Brammer, Hoejmose & Marchant, 2012); were evaluated using frequency counts (see Figure 4.12). The participants were of the view that the main value and benefit of reporting was it enabled targets to be set and progress to be monitored. There was a consensus amongst the participants that the benefit of reporting was that it equally addressed supply chain pressures, promoted, and supported culture change.

The discussion gravitated towards the promotion and support of cultural change and the difficulties this currently presented. The understanding is that organisational culture of the SME is built on the founder-managers values and skills (Petts, 2000). The belief among participants was that communication among management and employees was a key to an ethos of promoting and supporting culture change however, this needed to be managed carefully. Reporting, the participants felt needed to be introduced from the perspective of improving the skills of the business and not directly based upon a cultural or organisational change perspective. To promote reporting therefore, the participants were of the opinion that the value and benefit of this activity needed to emphasise the ‘*added-value*’ that the additional workload would bring so that the business would not see the process as an onerous task.

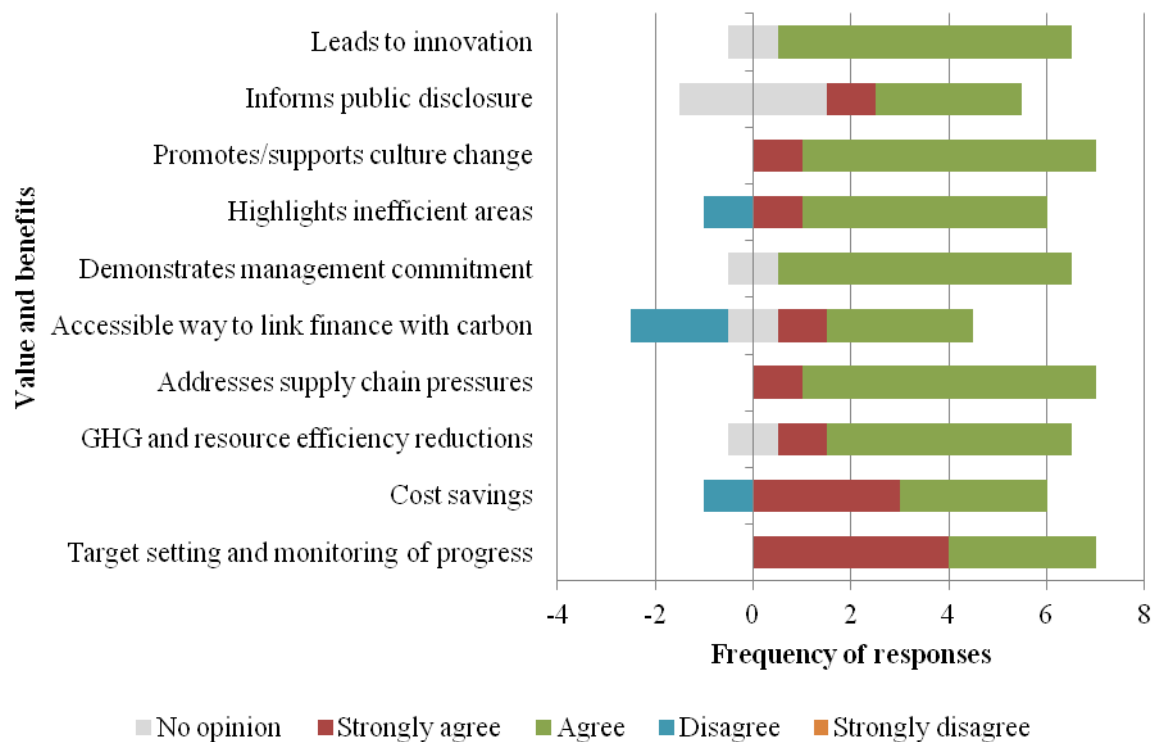


Figure 4.12: Responses from employees to the values and benefits of reporting GHG emissions

4.3. Summary

This chapter presented the results of a survey from service industry SMEs and established what data was available that could be used to determine the amount of GHGs being produced. The study demonstrated there was no significant association between the scale of the business and data availability and accessibility and the SMEs would continue to struggle with obtaining Scope 3 data, which was where the greatest impacts resided without external support.

The importance of Scope 3 data from the respondent SMEs was seen in establishing baseline GHG emissions values to guide reporting thresholds and, identifying cost saving opportunities and efficiency improvements. Subsequently the study established, the respondent service industries, produced on average 70t CO₂e per year. Baseline values to guide reporting thresholds for sole, micro, small and medium were established however, these would need further validation especially, for medium businesses, which was based upon eight samples.

In terms of baseline values however, a sole trader produced on average 5.3t CO₂e per year in providing their services; micro-businesses 18t CO₂e per year, small businesses 77t CO₂e and medium businesses 336t CO₂e. Confirmation of these values within the published literature was inconclusive because of the paucity of uniformity in the quantification of GHG emissions and comparative data for SMEs.

To reduce GHG emissions three scenarios were proposed and modelled based upon activities with the largest impacts that were highlighted in the analysis. The scenarios developed showed that the adoption of portable computers, greener fuel options and video-conferencing would reduce GHG emissions and the latter two, would result in significant financial savings.

Data from a roundtable discussion to establish the views and opinions of service industry employees relevant to measuring, managing and reporting GHG emissions is presented. The discussion findings show SMEs will struggle to minimise their emissions without a long-term government strategy that features funding, technology, training, communication, and standardised accounting frameworks. The participants are receptive to the notion of the mandatory reporting of GHG emissions unlike owner-managers who do not favour this option to control emissions because of the perceived cost of maintaining and implementing the system.

The online survey highlighted that data is available from owner-managers that can be used to quantify emissions and there is a potential to reduce emissions and therefore, costs by considering alternative approaches to established business behaviour practices. Lack of specialist staff was also featured as a concern by owner-managers in terms to not wanting mandatory reporting; this was

equally a concern to employees who felt that lack of skills was a main barrier that hindered the minimising of GHG emissions.

The adequacy of available *tools* and *rules* for instance EMSs and carbon dioxide equivalents as a metric of choice presented to SMEs proved to be unsatisfactory. Findings demonstrated that an EMS is not a suitable *'tool'* to incorporate the measuring and managing of GHG emissions. The system is voluntary, has a low *take-up rate*, only 10% of SMEs are at prominent operational stages, regional differences are apparent; limited businesses are attracted and the current trend appears to be a reduction in implementing an EMS. The focus upon carbon dioxide equivalents as the *'metric of choice'* found amongst the employees acute concern of using CO₂e as a quantifying metric to gauge impacts. The participants felt that using this metric exclusively would be misleading because wider environmental impact details would be lost (see p.90).

Accordingly, approaches to assessing the aspects of SMEs to determine their environmental impacts, which could use readily available data, which would consider a range of impacts, that accommodated the concerns with skills and costs was considered. Subsequently, a magnitude approach to assessing the aspects of SMEs and a pragmatic approach was configured, the former, using the ReCiPe method and the latter, evaluation of aspects using guidelines and protocols as detailed by Graedel (1998).

To determine the suitability of these RLCAAs for SMEs in assessing environmental aspects, data needed to be collected from small businesses to test the approaches. Accordingly, Chapter 5 defines the three case studies and the models that were created, upon which data was collected and the approaches trialled. The focus of the case studies is SMEs from service industries because of their increased prominence in the UK and, collectively in terms of numbers; there is potentially a *'significant'* contribution to emissions.

Chapter 5

Creating and Defining Case Study Models

This chapter defines the case studies in this research, to build the models that were used to trial the two rationalised life cycle assessment approaches (RLCAAs). The chapter forms the foundations to meet the third objective; to assess environmental aspects (see Chapters 6 and 7) and the fourth, to compare and contrast findings from the approaches to determine their suitability for service industry SMEs (see Chapter 8). The three service industries used for the case studies reflected the heterogeneity of SMEs; embracing both customer-facing and e-business services; were considered growth services or no systematic study on assessing the environmental aspects for that service industry was evident. Accordingly, the chapter is divided into three discrete sections.

The first section defines a company that focuses upon the packing and freighting of items brought at auction. The second section, concentrates on a film and video production company and the third section, is directed at an online distance learning (ODL) company and its provision of courses to students. Each of the sections provides a profile of the company, establishes the goal, scope and functional unit, describes the system and boundaries and, particularises the data and assumptions used in the models to assess the environmental aspects for the identified service in each of the three SMEs.

5.1. Packing company

The company used as a case study offers three main services; packing and shipping, mailbox facilities and a print and copy service. The main business activity is from the print and copy service that generated approximately 53% of their business; the packing and shipping, 32% and the mailbox service, 15%. The company employed a local workforce totalling six full-time employees. The employees work on average 43.6 hours a week in leased business premises. The premises are a Georgian building and the company occupies a total floor space of approximately 131m².

The freighting of antiques and fine arts is a growing sector, attributed to increased globalisation of the art market (Freight line solutions, 2013), whereby highlighted hotspots that may result from this research are operationally generic in terms of the packing for visual artworks. The packing and freighting of oil paintings and prints (hereafter referred to as pictures) was considered appropriate to be assessed because it is the company's most common shipped product. Pictures constitute 68% of all fine arts and antiques that are freighted by the company (see Figure 5.1.). The tare weight of the picture (2.4kg) was determined from the average weight of the most frequently used shipping

boxes⁴ (art boxes). The destination for the majority of goods is international which provides for 71% of their business with the European and domestic destinations constituting 20% and 9% of business respectively.

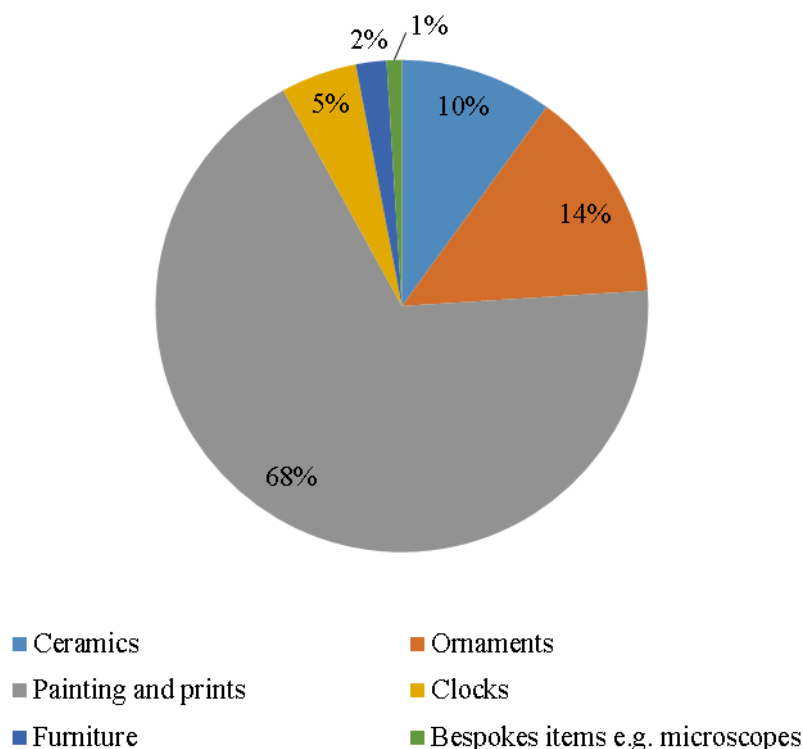


Figure 5.1: Percentage of items packed and transported by the packing company

5.1.1. Goal and scope

The goal and scope for both assessments were to compare directional information provided by the approaches at quantifying environmental impacts and to identify hotspots, from the service that provided the packing and freighting of artworks. The functional unit therefore, was to provide a packing, packaging and transport service for a picture with a mean average weight of 2.4kg transported from the auction house, packed and freighted to its collection hub in the USA.

5.1.2. System description and boundaries

The system considered is a 12m² packing unit, which forms part of a delivery, parcel, courier and postal service located in Avon and Somerset. One person packed the picture, which took 30 minutes. The process involved using a variety of packing materials, the use of office electronic equipment, energy consumption, and consumable goods used in the office, for instance, toner. The equipment used included a desktop computer and accessories, printer, monitor and a set of parcel weighing scales purchased from local suppliers. The packing unit is not heated and the service is

⁴ The shipping boxes are commercially produced by the company's supplier in three main sizes; regular (400mm x 50mm x 500mm); large (700mm x 90mm x 500mm) and extra-large (800 x 90 x 600mm). The company re-ordered and used the large art box more readily; 75% more often than the other sizes boxes and the average weight of a picture using this box size was calculated at 2.4kg.

undertaken in ambient temperatures because artificial temperatures caused by heating the facility may cause damage to the picture.

The service boundary in terms of the disposal stage was for the waste cardboard cores and attached residue tape to enter the municipal facility where it is incinerated or land filled. The solid waste produced from the service was minimal because any excess packing was appropriately treated and used as filler to cushion and protect other items of artwork that were freighted. The service boundaries and stages in this study are presented in Figure 5.2.

The service provided by the company includes transporting the picture to the packing facility from the nominated auction house. On site, the picture was packed for freighting. In the packing facility, the packing process was as follows:

- Card was measured to size, cut and placed over the top of the canvas to protect the picture and secured with low-tack masking tape
- A sheet made from foam was placed on top of the card and secured with low-tack masking tape
- Hardboard was used as a backboard, appropriately sized and was placed over the top of the foam sheet and secured with low-tack masking tape
- Polystyrene blocks were then attached to all four corners of the picture and secured to protect the frame from points of impact
- The picture was wrapped in a thick layer of bubble wrap and secured with masking tape at the back of the picture
- Polystyrene packing *peanuts* were placed inside the bottom of the art box
- The picture was put into the art box and secured from movement with the addition of further packing *peanuts* along the insides and top of the box
- The art box was taped securely with heavy duty packing tapes and label fragile tape applied to the box
- The picture was given a unique tracking bar code
- The art box was addressed, *shipping* documents prepared and arrangements made with the courier service for the package to be collected
- The courier service transported the picture to the airport where it was air freighted to the USA
- In the USA the picture was transported to its customer *hub* where arrangements were made for collection or additional delivery services

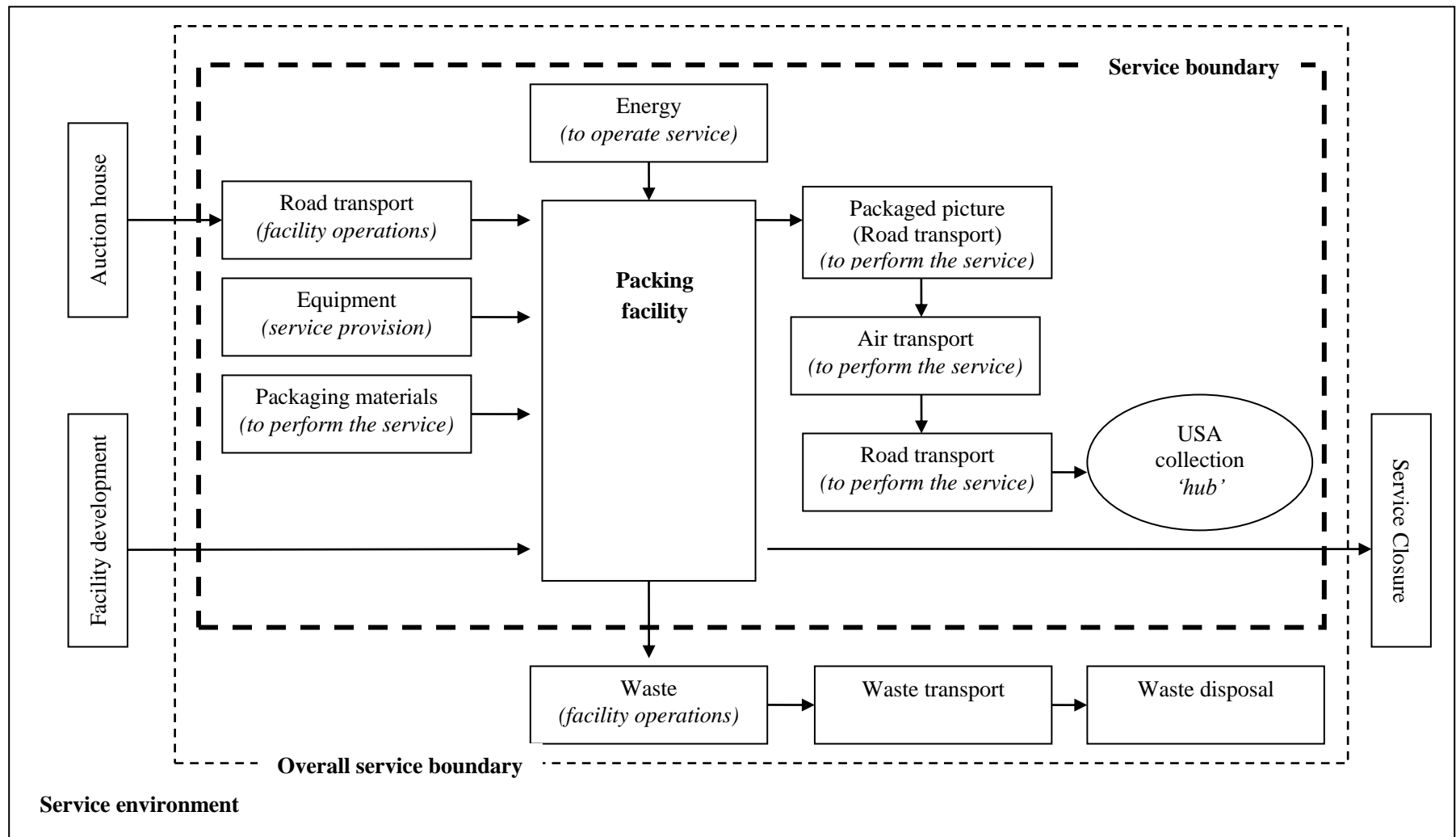


Figure 5.2: Service boundaries used in the packing, packaging and freighting study

5.1.3. Data inventory and assumptions

A combination of primary and secondary data was used in the inventory (see Appendix D: Tables 5-1; 5-2 and 5-3). The site-specific data was collected from a combination of two main one-hour site visits, email and telephone communication. The site-specific data was used for processes in the service provision that was controlled, owned or operated by the company and they supplied information for the amounts of materials.

When primary data was impractical and not possible because of resource constraints and the reluctance of suppliers to provide information that was deemed confidential, secondary data was used. Secondary data, which consisted of data for the production and composition of materials used to conduct the service, were calculated using proprietary databases, in this instance, Ecoinvent and peer reviewed publications. Subsequently, to develop the data inventory, a number of assumptions had to be applied because of the lack of data from upstream supply chain processes and these are outlined below.

A number of assumptions were applied to the model that concerned the electrical equipment; packing materials, office consumables, transport, energy use and waste. The electrical equipment used to deliver the service consisted of a desktop computer without a screen, a 17" CRT computer monitor, a keyboard, a mouse and printer. To the electrical accessories, the known estimated life period of the products was applied. The life periods for the computer and accessories was estimated as lasting for 10 years, for an annual average of 150 pictures. The toner was accounted for in the printer and assumed to have used 24 toners over 10 years and the weigh scales was composed of predominately stainless steel and alumina and assumed to be of equal weight.

In relation to the packing materials a number of assumptions were applied in the development of the model. Low-tack masking tape, 95% of the constituent material was paper and 5% was assigned to adhesive. The plastic composite tapes for instance, the packing tapes MBE, brown and fragile tapes were modelled using polypropylene granulates. The card sheet was based on an assumed similarity to packaging paper and the hardboard was assumed to be composed of wood fibres and urea glue. While the art box, used to contain the wrapped picture was modelled to include the processing of corrugated mixed fibreboard that formed the single walled box.

To freight the picture, paper documentation is necessary. The shipping documents, which included storage records, weigh bills and client shipping forms was included. The assumption was that each sheet of paper was wood-free and uncoated. The assumption for courier transport was a small-fleeted truck is used to transport the packed picture, as this was comparable with the service provided by Dalsey, Hillblom & Lynn (DHL).

The electricity use was modelled based on the UK electricity grid mix, (DUKES, 2009). The total energy consumption for the service was based upon observing the operational work place practices within the company and talking to the packing operators.

The packing unit's production of waste is 30g per week that cannot be recycled because it is mixed containing cardboard cores from the inner packaging tapes. Based upon 150 pictures per year, the amount of waste per picture was ~10g. The assumption was made that this waste would be disposed of as packaging cardboard, would be incinerated at the municipal waste plant, and for any solid waste that may remain this would be land filled. The disposal of the office's electrical products was not modelled as this was outside the considered scope. In addition, to obtain the process energy consumption from operational and user mode specifications the watts (W) to kilowatt-hours kWh conversion formula was used as appropriate.

$$E_{(kWh)} = P_{(w)} * t_{(hr)} / 1000$$

[1]

5.2. Film company

The company produces digital media, which includes the production of film, video, motion graphics and animation, but concentrates on film and video production, which provides the majority of their business. The company's film and video production can be classified in relation to their filming genre. The company offers a service that films documentaries, dramas, corporate events, commercials and community projects. The majority of filming has been locally produced documentaries; which comprises of 56% of their filming projects (see Figure 5.3). The genres have identifiable and distinguishing characteristics, the pertinent features and differences are presented in Table 5.1.

Table 5.1: Characteristics of filming projects undertaken by the film company

Filming projects	Characteristics
Commercials	Advertises a product or a service; specialist filming and production crew
Corporate projects	Filming of events for businesses for instance the informative launch of a product or new service; specialist filming and production crew
Community projects	Filming undertaken within the community; use of non-specialist filming and production crew; part of their societal sustainability
Dramas	Filming of a play or show using a specialist filming and production crew
Documentaries	Factual filming, a specialist filming and production crew

The company was formed in 1993 and undertakes work locally (within the southwest), regionally (within the UK), and internationally. The company leases three floors of approximately 93m² in size, in a Regency townhouse built in ~ 1795. The site was already developed into appropriate facilities suitable for companies that need an office base. The company employs six core full time employees and uses a contracted freelance team for specialist productions; is conveniently located and easily accessed using the public transport network.

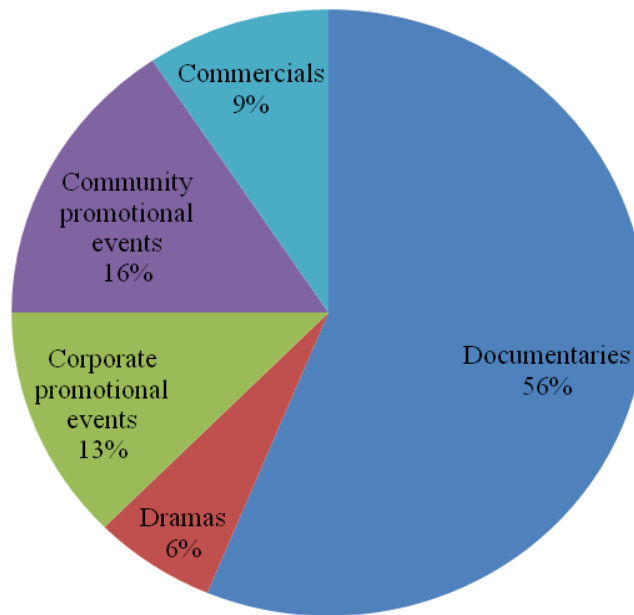


Figure 5.3: Filming projects undertaken during 2009-2010 by the film company

5.2.1. Goal and scope

The goal was to determine the potential sources of environmental impacts and suggest improvements in environmental performance using the two RLCAs. The intention was to generate results that are intended to identify the relative impacts of different aspects of film and video production. The functional unit for this study was the average requirements to provide the service to shoot, produce and edit one minute of filmed documentary. The reason for a very specific functional unit is that each of the filming projects requires very distinct parameters in their filming and production activities. The requirements to film an animation is distinct from filming a commercial in terms of crew, equipment and location provisions. The relevance to the company and the ability to communicate the findings easily to technical and non-technical stakeholders reflects the project and temporal focus.

5.2.2. System description and boundaries

To assess both approaches a model was developed to categorise the operational activities of filming a documentary. The model consisted of three operational stages; the first was the development or pre-production stage; the second, production and the final stage was post-production that concentrated on the editing and digitising of the film footage.

The operational activities and sequence of the service provided by the company in the filming of a documentary within the modelled stages was as follows. In the pre-production stage, a documentary filming project involves transportation to the client to discuss the documentary, office

administrative support in the form of opening a project paper file, drawing up contracts, invoices and compiling filming and shooting schedules and visiting locations. The focus of this stage is the use of office supplies and energy consumption for office facilities and transport. The average time afforded for this support in this stage was a total of 7.5 hours or one day.

The production stage involves the use of filming hardware and software, filming on location and administrative support at the studio after each day of filming for a four-day period. The majority of operational activity for this stage was on location and away from the studio offices. The post-production stage; took place at the office studios where the operational activity involves five days in the studio editing and digitising the documentary footage. The activities accounted for in this stage involve energy consumption, administrative support and the use of post-production film equipment and the contribution of project members. The operational distribution stage that includes internet and web site streaming was excluded from the service boundary. The service boundary also excluded office furniture, and the disposal of office furniture and electrical equipment. The service boundaries for the documentary study; is entitled concept-to-realisation and is presented in Figure 5.4.

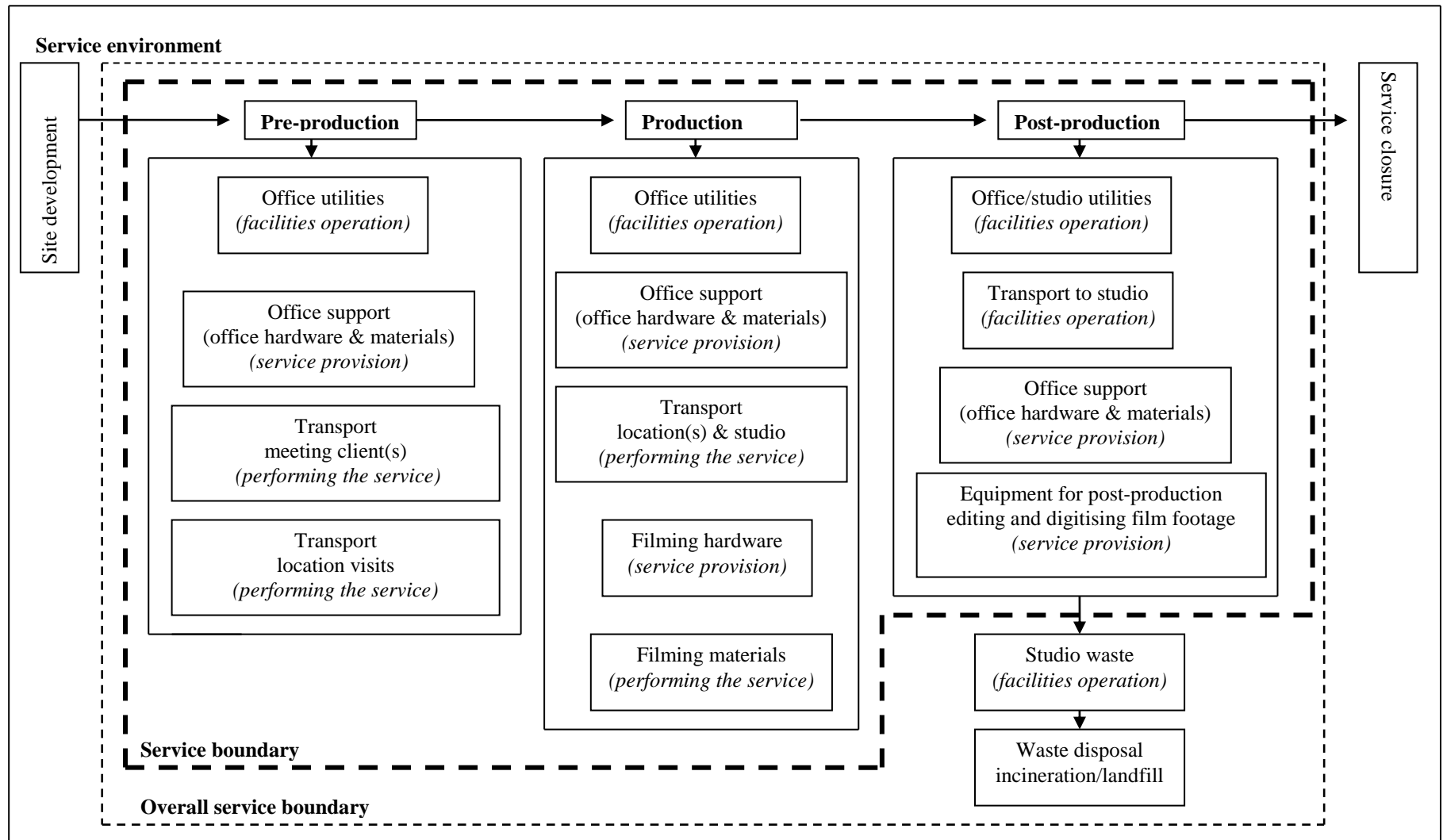


Figure 5.4: Service boundaries used in the study to film a documentary: *concept-to-realisation*

5.2.3. Data inventory and assumptions

The model of the system was developed from a combination of primary and secondary data. The latter data type was obtained from published data base sources most notably Ecoinvent (2007). The former data type was collected directly from the company's project folders. The paper project folders contained all the information for that particular filming project. The information contained in the folders consisted of; copies of expense claims for location travel, filming and shooting schedules; on site filming equipment requirements; crew requirements, numbers and specialism required for the shoot; mileage logs, equipment registers, project brief and dates.

To clarify the information in the project folders; face-to-face interviews were held with operational representatives; telephone discussions and email was used. In addition, film locations were visited to observe the filming process to contextualise the data. The model developed necessitated the inclusion of specialist production and post-production filming equipment. The information needed to represent the equipment's component materials were based upon manufactures equipment specifications manuals noting electrical and technical specifications.

To develop the service-model a number of data collection assumptions had to be made in assembling the data inventory. The data for electricity, heating and water was obtained from utility bills and averaged over 12 months to get a monthly profile, with a daily profile calculated and based on a working occupancy of the building for a five-day week. The daily rate of electricity used was reported as 10.96kWh and gas used for heating 53.09kWh. The water usage was based upon 0.15m³ for one employee per day, on-site in the studio. The data for electricity was modelled for 1kWh and based upon Dukes (2009); while water and gas, used in the model employed suitable proxies from the Ecoinvent database (2007), for instance to represent water within the system '*Tap Water at User*' was used. To denote a small gas heating condensing boiler the proxy '*Heat: natural gas at condensing boiler*' was used. The quantity of gas consumed was converted into kWh and MJ as appropriate in the development of the model.

The system boundary included three main transport streams. The average distance was used calculated from travel logs and expense claims to estimate location visits, meeting clients and location filming sites for the documentary genre. In terms of office consumables that consisted of office paper, printed-paper and copy paper these were quantified based upon the average weight and sheets of paper per documentary project file. Office stationary however, such as pens and erasers were excluded from the model.

The identification of filming, editing and digitising equipment for use on a documentary was identified from the project folders and discussions with filming operators. The use of information on life periods for the equipment was particular to the company and obtained from discussions with

operators. In relation to the materials used to construct the equipment, where data was not available a suitable proxy was selected to represent the environmental burdens of the material used in the equipment based upon visual immediacy, mass of the two main components or how crucial the component is in the construction. For instance, in terms of a telephone the component's visual immediacy is the ABS plastic, which constitutes the bulk of the equipment's mass, which crucially needs an electronic base for instance, a printed wiring circuit board to function as a telephone.

The studio waste was modelled on the average amount produced over a 14-day period; resulting in 4g being generated per day. The waste consisted of mixed plastics for instance, packaging, and filming cuttings produced from editing the documentary. This equated to 20g resulting from 5 days of studio work, editing the documentary. The disposal of the waste was modelled with 20% incinerated and 80% to landfill, with both streams transported and disposed of at the local municipal waste plant. Accordingly, in line with the methodology for attributional studies average data and not marginal, was used to create the data inventory. A list of the components and data used to assemble the inventory is contained in Appendix D: Tables 5-4 and 5-5.

5.3. Online distance learning company

A small commercial online distance learning (ODL) company located in southern England providing accredited foundation degrees and postgraduate business and management courses provided the focus for this case study. This case study conducts most of its business processes and activities online, electronically over the internet, exemplifying an e-business, with no direct physical contact with its customer.

The company provides ODL courses focusing on business and management. The company offers HND/HNC (higher national diplomas and certificates) foundation degree courses through to postgraduate courses; with accreditation enabling direct entry qualifications onto first-degree courses to traditional campus based universities in the UK, USA and Australia. The company was started in 2005, and has a turnover of approximately £700K. The office is located on an industrial park above a plastics manufacturing unit and covers a total floor space of 268m². The industrial park sites a wide variety of smaller process and product businesses from agricultural ironmongery, weighing machine manufacturers to sheet metal and plastic fabricators. The company rents three offices in the industrial park and the rent is all-inclusive of utilities, water, waste and electricity, there is no provision made for gas.

There are two core employees, an administrative assistant and an office manager, who deal with the student applications, public queries, and enrolments. The managing director is based in this office and presides over the daily operations of the company and personnel. The personnel in this

instance consist of ten self-employed tutors, who have an average of 75 HND students. The company provides, in total ODL courses to currently 1002 students.

5.3.1. Goal and scope

The goal is to assess the environmental aspects, to provide and perform an ODL service for a Level 5 HND Business Management course undertaken by one student that is equivalent to 240 credits⁵. This particular ODL course was chosen as it is the most popular and widely recognised. The results were used to understand the relative environmental impacts of different aspects of providing an educational ODL service and suggest mitigation approaches to reduce the overall environmental impacts to provide and perform the service. Accordingly, the functional unit is therefore, to provide and perform an ODL service for a Level 5 HND Business Management course over a 24-month period that is equivalent to 240 CATS for one UK student studying part-time based at home.

5.3.2. System description and boundaries

The overall system boundary considered four discernible sub-systems; home-based; network-based; local-based and regional based activities. The home-based sub-system is characterised by the student and tutor based in the home environment. The home environment is particularised for both parties by electronic equipment, furnishings and energy use necessary for the student to undertake the course and the tutor to provide support and guidance throughout the 104 weeks or 24 months.

The network-based sub-system features the Virtual Learning Environment (VLE) and is represented by the energy used to run Modular Object-Oriented Dynamic Learning Environment (Moodle) and the company's Website. The e-learning platform and the website are both externally hosted and access to the former is permitted, once the student has paid their fees and funds cleared. The student is then allocated a tutor and login details to Moodle. The VLE contains all the core-teaching materials for the HND course that have been digitised for all six units, in addition to support and course administration materials.

The local based sub-system considers the activities within the office facility. The sub-system addresses the employees travel, the materials and energy consumption used by the office appliances, for instance, computers and printers; and used by the electrical appliances for instance, microwave, kettle and fridge. In addition, office furnishings and consumables such as paper are accounted for and the waste, water, heating and lighting that are needed to provide and perform the service for one student. The regional based sub-system focused upon meetings related to the

⁵ The credits are a comparative variable to the credit accumulation and transfer scheme (CATS), utilised by UK universities in modular degree courses to facilitate movement between courses and institutions.

course, for instance, moderation meetings with the examination and awarding organisation, Edexcel. The overall system boundary for the company used in this study is illustrated in Figure 5.5.

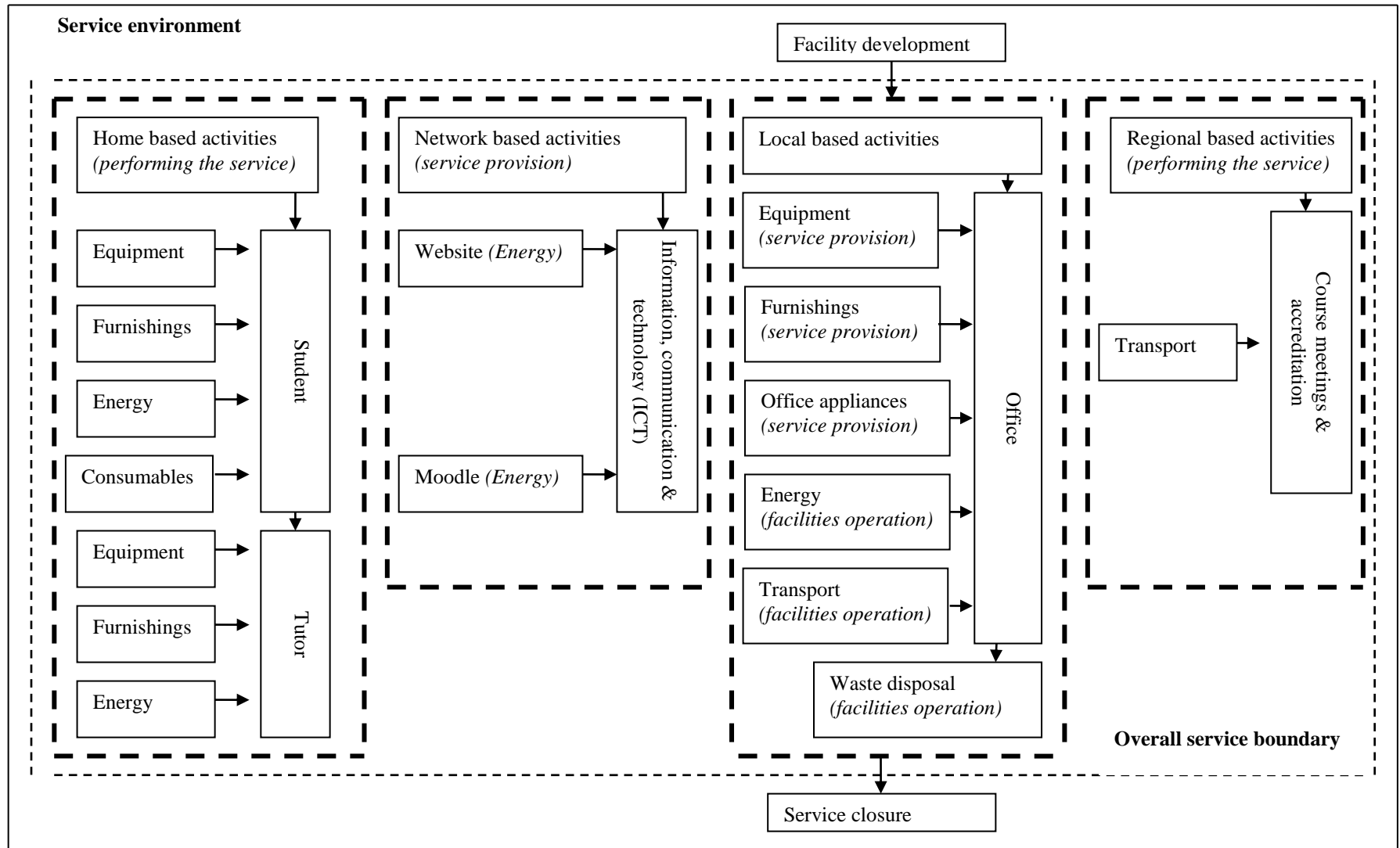


Figure 5.5: Service boundaries used in the study to provide an ODL HND Business and Management Course

5.3.3. Data inventory and assumptions

The data collected to develop the system model was obtained from primary and secondary sources using *bottom up and top down* approaches. The *bottom-up* data was collected from interviews and communication with the managing director, office manager and assistant administrator. To clarify the information collected from the interviews follow-up emails and telephone calls resulted. The data used to construct the student model within the home based activities system boundary was initially developed using course guidelines for the HND course. Then primary data was collected from the students who responded to an online survey placed on the company's student Moodle platform.

The tutor model was developed from monthly activity reports, which detailed the contact made to students in terms of advice, enquiries and assignments. The hosting service provider supplied the power data for the virtual learning platform, Moodle and the Website. In terms of the office-based activities the employees, provided the data and materials used and electrical equipment details was obtained from manufacturers' specifications and manuals.

A *top down* approach was employed using Ofgem national statistical data (Ofgem, 2011) for heating to construct and model consumption, within the home-base sub-system. The energy mix used to create 1kWh of UK electricity was modelled from Dukes (2009) and life cycle inventory data was taken from the Ecoinvent database (2007); IDEMAT (2008) and ETH-ESU (2010) as appropriate.

The acquisition of data; consisted of specific, generic and adapted. Specific or primary data was preferred however, to create the system boundary generic data from databases was used and adapted data that was modified from the databases and literature to reflect the functional unit. To capture the transmission of emails adapted data was used and calculated at 0.0009kWh per 1 Mb email to one person (Farrant & Guern 2012) and applied in relation to a UK electrical mix. To recognise the contribution of telephonic communication within the service 0.026kWh per 3 minutes of call time was applied (Von Weizsacker, Lovins & Lovins, 2006).

Additional equations that were used to develop the inventory consisted of converting the electric power in kilowatts (kW) to energy in kilowatt-hours (kWh) accordingly, the following were used:

$$E_{(kWh)} = P_{(kW)} * t_{(hr)} \quad [2]$$

The electrical appliances and electronic equipment and furnishings were complemented by the life expectancy of the product item. The use of this variable ensures that a proportion of the life of the

product is assigned to the functional unit and not all the impacts. The ratio equation used to calculate the portion of product per one student for the number of course years was as follows:

$$\frac{1}{\text{No. of students}} \times \frac{\text{No. of course years}}{\text{Life expectancy of the product}}$$

[3]

Accordingly, a desk within the local based activities boundary assigned a life expectancy of 10 years and based on the above calculation would produce the following result $1/1002 \times 2/10 = 0.0002p$. The data was used to create the inventory to carry out the assessment (see Appendix D: Tables 5-6; 5-7 and 5-8).

The acquisition of data and assumptions are described as appropriate under the following sub-headings that correspond to the sub-systems boundaries, of home, network, local and regional based activities.

5.3.3.1. Home based activities

The student model was initially developed from specific course rubric whereby the individual is recommended to study 10 hours a week⁶ and the course as a part-time option would last for 24 months. The online distance learning course would need the use of electronic equipment for instance, a computer, furnishings in the form of a desk and chair, tutor support and home utilities for instance, lighting and heating provision. The data for these attributes was developed from generic and adapted sources.

To produce an assignment a student would need to use two main consumables most notably paper and toner and have access to a printer. According to the company, the student cannot print-off chapters from their core books from Moodle because of copyright restrictions and they submit all assignments electronically. The student however will invariably produce a draft for each assignment prior to submission to check for any inconsistencies. The student for their course needed to produce and submit 16 assignments between 2,500-3,000 words in length. The assumption was applied that the student would produce 16 draft printed assignments with a word length of 3,000 words for each assignment, which equated in total to 48,000 words. One page of A4 sheet, it was assumed catered for 500 words therefore, 96 sheets of A4 paper was needed. The

⁶ The guide number of study hours for the course in the rubric is detailed as between 8-10 hours per week to complete the course within 18-24 months. The 'worst' case scenario was used and the data parameters were set at 10 hours of study per week. Accordingly, a total of 1040 study hours was attributed which equated to 104 weeks and 24 months.

ink needed to print the 96 sheets of paper was accounted for in the toner, which was assumed to provide ink to print 5,000 A4 sheets before a replacement or refill was needed.

The tutor has on average 75 students on different levels of business and management courses. The average tutor is contracted by the company to provide 40 minutes of supported contact time for one HND student per month, which equated to 16 hours for the duration of the course. Subsequently, their use of electronic equipment, and furnishings was based upon these parameters. The main difference, between the tutor and student model was, in the former no printing or toner use was accommodated and the economies of scale differed.

To capture the electronic communication within the home-based system between the office, student and tutor the use of emailing and telephone calls was modelled based upon the energy consumed. The data for this part of the model was based upon average figures provided by the company from monthly tutor contact sheets. Accordingly, the average number of emails transmitted by a tutor over the course in connection with a student was two per month, 48 for the duration of the course. To denote the student's activities in relation to electronic communications and the energy consumed within the home-based system; it was assumed that the student responded to the tutor's 48 emails and transmitted on average 5 to the office campus on administrative matters. Email communication between the tutor and office was based upon the responses to messages sent requesting monthly contact sheets and calculated based upon 24 transmitted emails, the energy used and the average number of students allocated per tutor.

To denote the telephonic communication within the system; between the tutor and student; the main call is at the start of the second year. The tutor telephones the student with a '*progress and guidance*' call that lasted on average 15 minutes per student and was modelled accordingly. The electricity used for lighting was based upon the assumption that when the student is studying or the tutor working the lighting was on. A task lighting of 60W was used and a main lighting fixture of 75W for 1040 hours; or 10 hours per week was modelled for the student. A similar model was developed for the tutor but in relation to the 16 hours of support and guidance.

The heating provision values within the home-based activities boundary for the student and tutor was calculated from generic data from Ofgem gas consumption figures, resulting in a value of 1.88kWh for one hour of gas. The assumption was made that gas was the main energy source and heating is provided throughout, the first quarter (January-March) and fourth quarter (October-December) months for the 24-month course in the context of the student's study hours and the tutor's support hours. Subsequently, heating based on this premise would be needed in total for 12 months of the course. In terms of the student, and based upon 9 hours of heating per week and 52 weeks this was equated to 468 hours, for the tutor, the model was based upon eight hours.

5.3.3.2. Network based activities

The virtual learning environment (VLE) as represented by Moodle was modelled on specific network power data provided by the business's external host company. The total network power needed to run Moodle was 500W. The platform is run at 500W power for twenty-four hours a day, seven days a week and is used by 1002 students, which equates to 0.50W per student user. The Moodle model was based on the HND course student spending 90% of their whole course study time logged on to Moodle. This produced a Moodle '*operational*' mode of actively engaging in the course materials on the platform of 1030 hours and 10 hours of '*idle time*' for the duration of the course.

The website is used by the company to market their courses and provide a portal to log into Moodle, thereby formed part of the learning environment. The site's analytics could not be obtained; which would have provided a valuable source of information because although it contains unstructured data, it could be used to add business intelligence data in the assessment of environmental aspects. The externally hosted server for the website has a power of 850W and is operational for 24 hours, seven days a week. The model was developed by assigning a watt value to each of the 1002 students (0.85W) and basing the operational time for a student user on 104 weeks and 17472 hours, which equated to the course duration of 24 months.

5.3.3.3. Local based activities

The local based activities were context within the office environment. The patterns of working were a five day 37.5 hour week, from Monday-Friday. This approximately equates to 225 working days (Monday – Friday) a year excluding bank holidays and 28 days paid annual holiday and therefore for the course 450 days was applied as appropriate to personal office equipment. In the instance, where the equipment was generic to the office 504 days was applied for the duration of the 24 month course, based upon an average of 21 working days per month. The office employees provided administrative support and advice to all 1002 students and to obtain the impact for one student user studying on the HND course this student was considered in terms of the whole student body of 1002 individuals.

The system boundary for this sub-system was based upon the specific student body of 1002 and was modelled in terms of this variable to obtain the impact for one student. The energy consumption for all office practices, equipment and appliances, lighting and heating was calculated from specific office data. The materials used in the construction of office equipment, appliances and furnishings were modelled on generic and adapted data. The kitchen appliances, for instance, fridge and microwave, office equipment, such as air purifier and electric panel heaters, and furnishings, for example desk and chairs were based on the mass of the constituent parts in excess of 5% of the total composition of the product or the three main materials. In the event where

specific material data was not available, a suitable proxy was selected to represent the environmental aspect of the material used.

The personal electronic office equipment was specific data based upon as appropriate two modes an operational (on mode) and standby (sleep mode). The use of this method produced a more authentic model and enabled subtleties to be highlighted, which can be used in developing improvement scenarios to reduce the environmental impacts of the system. The office's electronic equipment for instance, the desktop computers and screens were on operational mode for 6.5 hours; and 1 hour on stand-by and at the end of the working day the computer and all equipment was *turned-off* and no residual power was consumed. The printer was on operation mode for approximately 5 minutes to produce one invoice, and an average of 96 script pages that were needed for the examination board meetings that took place twice within the 24-month period.

The office owns and uses a 700W microwave to heat liquids and food consumed during working hours. To capture the contribution of this activity by the company usage data was collected from the employees for one week on the time spent heating food in the appliance. The average time spent heating food or liquids for this period were calculated at 1.4 minutes per day. The value was projected for the duration of the HND course, which equated to ~706 minutes or ~12 hours. In addition, data was collected on the weekly consumption of coffee. The average mugs of coffee drank by employees was 3 per day. The boil time to heat ~0.870ml of water using a 2.2kW kettle for 3 mugs was 2 minutes and using equation [2], kWh was calculated in relation to 504 days and 16.8 hours. The office has a coffee machine the average cups of coffee made using this appliance was one cup a day and heating 200ml of water, taking a minute to make one cup of coffee using a 1.3kW machine. The calculation therefore, considered the process in relation to 504 days and 8.4 hours.

The office uses an air purifier to deal with the dust and occasional odour from other businesses within the vicinity and the building. The air purifier has a turbo high power setting of 50W and a low power setting of 6W. The power setting used by the office was the low power setting of 6W. The air purifier was used for 7.5 hours a day and the model was developed that employed the low power setting and 3780 hours to represent the 504 working days. Three electric panel heaters heat the offices, each with a power of 2000W. The rented offices with the inclusive utility provision mean that the property owner controls the heat. The heating is *switched-on* in September until the end of March. The hours the heating was on, equated to 2205 hours for the duration of the course and calculated to include the three panelled heaters. The office lighting consists of 2 fluorescent 65W up-lighters and 14, 18W fluorescent light bulbs. The company kept all the lights on for the duration of the office working day. The energy used for the lighting was based upon 504 working days, which was equivalent to 3780 working hours.

Specific data for water used by the office could not be obtained and therefore, generic and adapted data was used. Office water use was based on the typical office measurement of 9.3m³ per year for an office employee from the environment agency calculated to acknowledge the presence and activities of the three employees in relation to student numbers (EA, 2012).

The waste produced by the office consisted mostly of sandwich and crisp packets and confectionary wrappers, polystyrene food trays, *Tetra Pak* cartons, paper serviettes, food waste and hard plastics from pen barrels and lids and padded envelopes. The actual waste arising was measured by the office for one week and this was calculated at 400 grams. The amount of waste was extrapolated for the 24-month course based upon the average working weeks per year, 52. The amount of waste based on 104 weeks was calculated as 41.6kg and per student 0.04kg for the duration of the course.

Once the student had enrolled the only telephone contact between the company and the student is, if there are problems, with tutors or payment of fees. The company will however, once the student has enrolled make an 'introductory' telephone call, which lasts on average 10 minutes, to ensure the student, is satisfied with their tutor and the course provision. The office will call the tutor once a month. This was modelled based upon an average yearly call time of 120 minutes, scaled-up for the course's 24-month duration and based upon the average number of students; the energy used in the call time was calculated. The office emails the tutor once a month for their student contact and time sheets. The duration of the course means 24 emails are sent. Accordingly, the energy used to transmit these emails is based upon the average number of students per tutor (75).

5.3.3.4. Regional based activities

The sub-system on regional based activities focused on business travel of the parties, the examining body representative, the average distance travelled by tutors and the travelling of the office manager and managing director from the company to meetings connected with the course. The main mode of transport used in this sub-system was the train and this was modelled using Ecoinvent generic data.

5.4. Summary

This chapter presented the case study models used to trial the two RLCAAs. The three case study models, created and defined for this study, reflected the heterogeneity of SMEs, were considered growth services or no study from a life cycle perspective on assessing environmental aspects for that service industry was evident. To assess the environmental aspects and be able to compare and contrast each of the approaches (*Objectives III and IV*); for each of the case studies the goal and scope; functional unit, system boundaries; the data collected and assumptions used to develop the

inventories and create the models are presented. The results from each of the case studies, using the two RLCAs are detailed in Chapters 6 and 7, respectively.

Chapter 6

Results: Magnitude Approach

This chapter presents the first part of the results relevant to *Objective III*, to assess the environmental aspects of selected SME case studies using RLCAAs. In this chapter, the results from the analysis using the magnitude approach that utilises the ReCiPe methodology and the SIMAPRO tool are presented. Guided by the selected SME case studies in the previous chapter; this chapter is divided into three discrete sections. The first section, reports the results from the analysis conducted on the packing company, the second, the film company and finally, the third from the online distance learning (ODL) company.

The results from characterised and normalised data are presented for the case studies on different elements of a service as per functional units specified in Chapter 5. The assessments using the results from characterised and normalised analyses identify hotspots; are utilised to develop scenarios and suggest improvements to mitigate environmental impacts and improve environmental performance. When appropriate, single-issue analysis is conducted, focusing upon carbon dioxide equivalents to context the findings with research publications on carbon emission studies.

6.1. Packing company

This section presents the results from the analysis on the packing company modelled on the parameters established and described in Chapter 5 (see p.98).

6.1.1. Impact assessments

Characterised results for the overall service boundary are presented in Figure 6.1 (see Appendix E: Table 6-1). The characterised data identified the relative contribution of different aspects of the service per functional unit. The main findings from the service using ReCiPe (midpoint) can be summarised as:

- The energy used by the service contributed to 83% of all the impact categories most notably to ionising radiation (~13%)
- The equipment used to provide the service contributed to every impact category, the largest contribution to metal depletion (~65%)
- The transport used to operate and perform the service also contributed to every impact category; especially climate change (~91%)
- Shipping documentation contributed to less than a quarter of the impact categories (22%), which were of minimal impact and ranged from ~1% to ~3%

- The packing and packaging materials used to perform the service contributed to 94% of the impact categories most notably, agricultural land occupation (~95%); freshwater eutrophication (~52%) and water depletion (~41%)
- Waste contributed to 72% of all impact categories, contributing ~66% and ~57% to the ecotoxicities freshwater and marine respectively, and ~51% to human toxicity
- In relation to the overall service boundary waste contributed to less than a tenth of the overall environmental burden resulting from providing the service (~9%)

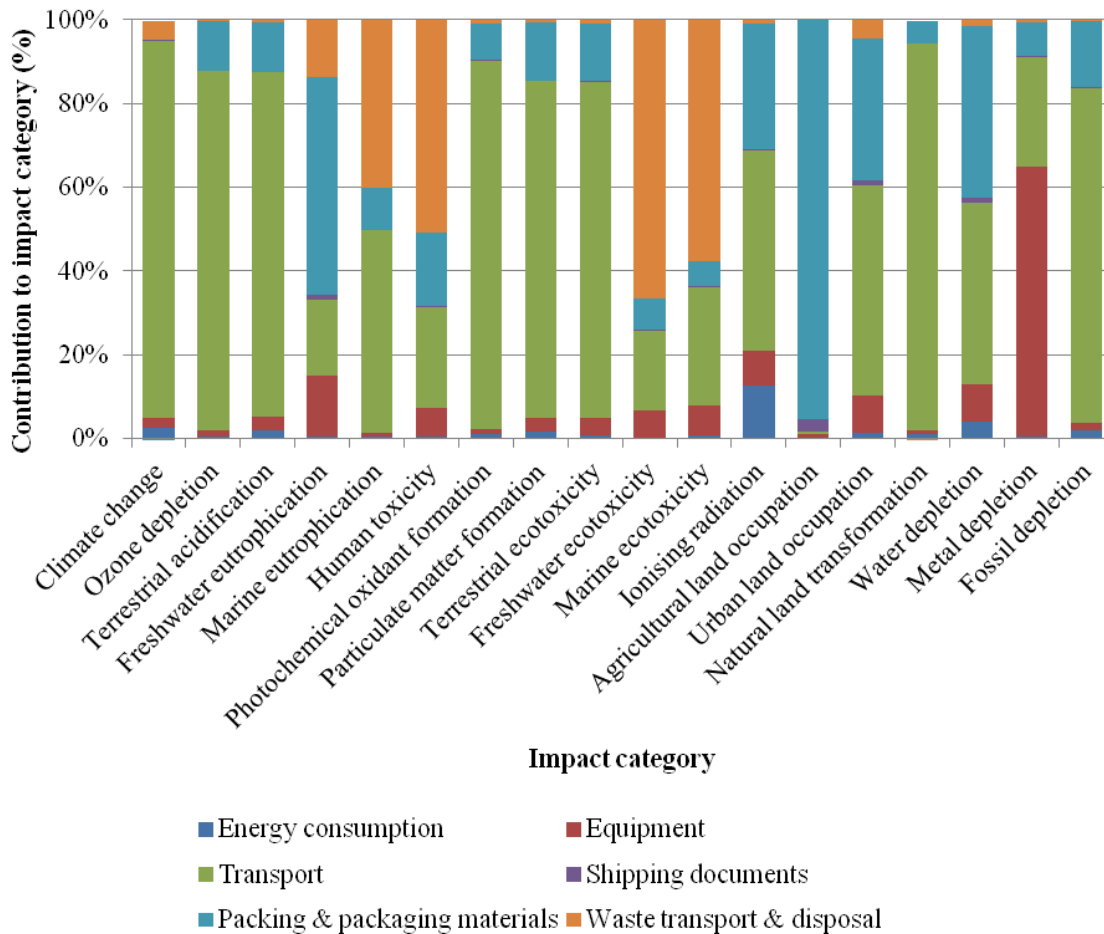


Figure 6.1: Characterised data for the packing, packaging and delivery service for a picture freighted by the packing company - ReCiPe midpoint (H)

At this stage of the analysis, the focus of the study was directed towards the elements used in the packing, packaging and delivery service, and the service boundary, which contributed to ~91% of all the impacts, because this was where the significant impacts resided. In addition, the impact categories considered were reduced because of the need to obtain *settled* and study specific categories (Guinée, 2002) (see Chapter 3, pp.50 & 52). The impact categories used are represented in Figure 6.2. To establish the relative magnitude of impact categories in relation to aspects of the service, the data was normalised (see Figure 6.2) (see Appendix E: Table 6-1).

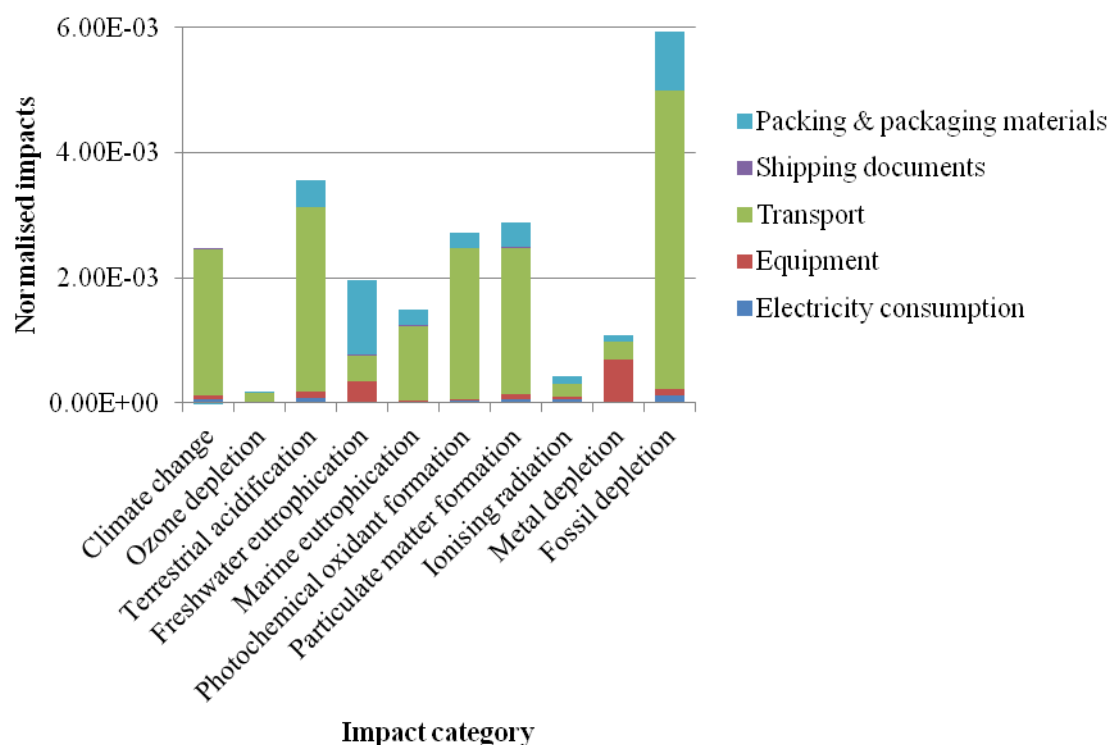


Figure 6.2: Normalised impacts for the packing, packaging and delivery service for a picture by the packing company as represented by the service boundary - ReCiPe midpoint (H)

The normalised findings identified the main environmental aspects as transport, packing and packaging materials and equipment, which contributes to ~75%; ~16% and ~7% respectively. The main impact categories affected by the service are fossil depletion, terrestrial acidification, and particulate matter formation. To provide the service, ~26% is contributed to fossil depletion; ~16% to terrestrial acidification and 13% to particulate matter formation. Fossil depletion is influenced by the use of fossil fuel in transport and oil based packing materials. Terrestrial acidification is affected by the production of airborne acidifying emissions, nitrates and phosphates resulting from the use of transport and production of packing and packaging materials. The emissions are deposited on the soil changing its acidity, which has a cumulative potential to cause changes in species occurrences. The particulate matter formation arises primarily from transport and results from the combustion of fossil fuel and the subsequent release of inorganic and organic substances, which has the potential in damaging human health. To identify the significance of specific aspects of the service within the life cycle, the relative contribution of each factor was determined by further analysis on the normalised data. The results are presented in Table 6.1, which recognises the significant processes.

Table 6.1: Relative contribution using normalised impacts for the aspects of the service provided by the packing company - ReCiPe midpoint (H)

Aspects	Aspect control	Total impacts (“People emission equivalents”)	Relative contribution (%)
Transport (<i>air</i>)	In direct	1.62E-02	71
Specialist packaging (<i>art box & sheeted card</i>)	In direct control	2.01E-03	8
Equipment (<i>office equipment</i>)	Direct control	1.51E-03	7
Packing (<i>polystyrene ‘peanuts’</i>)	Direct control	1.17E-03	5
Electricity consumption	Direct control	4.15E-04	2
Transport road (<i>UK courier</i>)	Direct control	3.29E-04	2
Transport road (USA) (<i>airport depot-customer hub</i>)	In direct control	5.11E-04	2
Packing tapes	In direct & direct	3.09E-04	1
Total other (<i>packing consumables, transport & documentation < 1% contribution</i>)	Direct & in direct control	2.58E-04	1
Totals		2.27E-02	~100

(process of value approximations, figures do not necessarily total to 100%)

The addition of the column labelled aspect control acknowledged the type of operational control the company had over the aspects. Of interest are those that the company has direct control over and contributed 5% or greater relative to the total impacts against the service boundary. The use of aircraft freight to transport the picture to its destination contributes to 71% of the processes. This aspect is not directly controlled by the company and although differing modes of transport could be employed in delivering the picture, time and customer demands means this aspect is immutable. The company uses specialist packaging to pack the picture; although not a perquisite, this is indirectly controlled by the company because specific packaging needs to be used to transport the picture safely and legally across the Atlantic. The office equipment that is used to provide the service is directly controlled by the company and could be addressed to reduce impacts. The packing material especially the polystyrene *peanuts* are directly controlled by the company and could be considered in the reduction of overall impacts.

6.1.2. Interpretation

This section discusses the significant issues and determines the areas that can be improved to reduce the service’s environmental burden. Two scenarios were developed based upon the direct control the company had over their processes and materials. The environmental hotspots that the company had direct control over were their office equipment and the use of the component polystyrene *peanuts*; that functioned as a cushion to physical impacts and filler in the packing process. The three significant impact categories that the computer and accessories contributed to were metal depletion (~51%); freshwater eutrophication (~25%) and terrestrial acidification (~6%) and the polystyrene *peanuts*, fossil depletion (~43%), climate change (~13%) and freshwater eutrophication (~12%).

To reduce the environmental impacts of the service two different scenarios were developed to see their effects on the system. In the first scenario (A), a model was developed that considered the computer and accessories used to provide the service. The age of the equipment used by the service means that *green* purchasing could be considered as options to reduce the service's impacts. A comparative aspect acquired from the Ecoinvent database, laptop computer at plant was used. The model was developed on the worst-case scenario and the laptop was modelled with a power of 50W, with no standby feature or sleep mode and switched on for 7 hours. For the service, a UK electricity grid mix was used and an energy use of 0.35 kWh was assumed for the activity. In addition, further amendments were made to the model and the CRT screen, desktop computer without screen and the standard version keyboard was removed from the base service case.

In the second scenario (B), the petroleum-based polystyrene was replaced with a starch-based alternative, which was developed within the industry as an environmentally friendly alternative. The assumption was made that the main material for the *peanuts* was starch-based and the base model was modified using a database surrogate process obtained from Ecoinvent; *modified starch at plant*. The category indicator results were normalised and the base case was compared to the scenarios to determine the relative significance of the impact categories (see Figure 6.3).

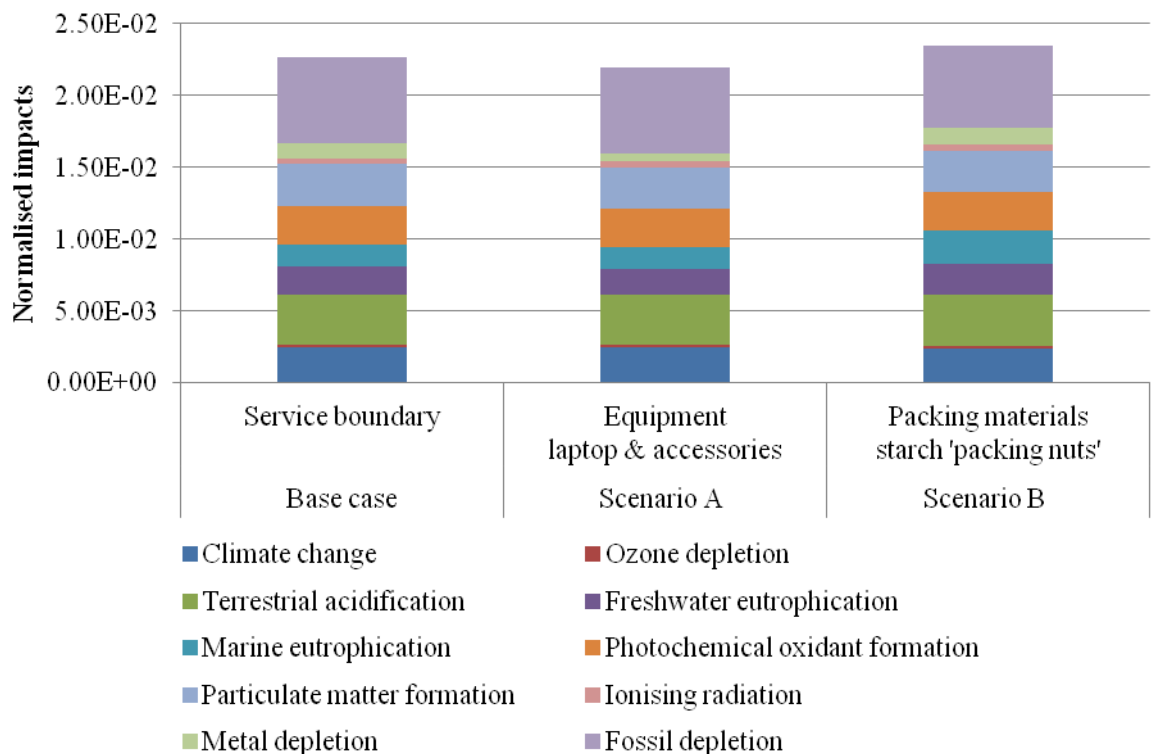


Figure 6.3: Normalised impacts comparing substituted materials & components identified as introducing potential improvements to the system with the packing company's current (base) position - ReCiPe midpoint (H)

The purchase of a laptop and accessories would reduce the environmental impacts of the service. The findings show that relative to the base case there would be reductions in the burdens on metal

depletion by ~44%; freshwater eutrophication by ~10% and terrestrial acidification by ~1%. The main reduction in the impact associated with metal depletion is understandable as the laptop already has a screen and a keyboard while the desktop computer uses additional accessories that need functioning metal components. To deliver the packaging service using scenario (A), this would result in the overall environmental burden for the service reduced by ~3% and a reduction in 70% of the impact categories presented.

The use of starch in the modelling of packing *peanuts* relative to the base case resulted in a ~3% reduction in fossil depletion and a ~2% reduction in the burden on climate change. However, there was an increase in the burden on freshwater eutrophication by ~11% with 50% of the impact categories showing an increase in environmental burden relative to the base case. Subsequently, the use of starch as a component in the packing material using scenario (B), resulted in a 4% increase in the environmental burden to deliver the service. This result can be attributed to the burden placed upon marine eutrophication which increased by ~53% resulting from the run-off from slurry spreading used in the cultivation of maize needed for the composite starch materials to produce the *peanuts*.

To reduce the overall environmental burden of the packaging and delivery service, scenario A is only feasible within the control parameters. Seventy percent of the impact categories saw a reduction in impacts to the environment however; these were minimal (see Figure 6.4). In terms of the overall service boundary, the application would result in a ~3% reduction in the environmental burden for the service overall. There were increases however, in emissions for ozone depletion by ~2% and climate change by ~1%. Both these impacts are attributed to the assembly processes used in the manufacture of the laptop resulting from the polymerisation of tetrafluoroethylene used to produce the product.

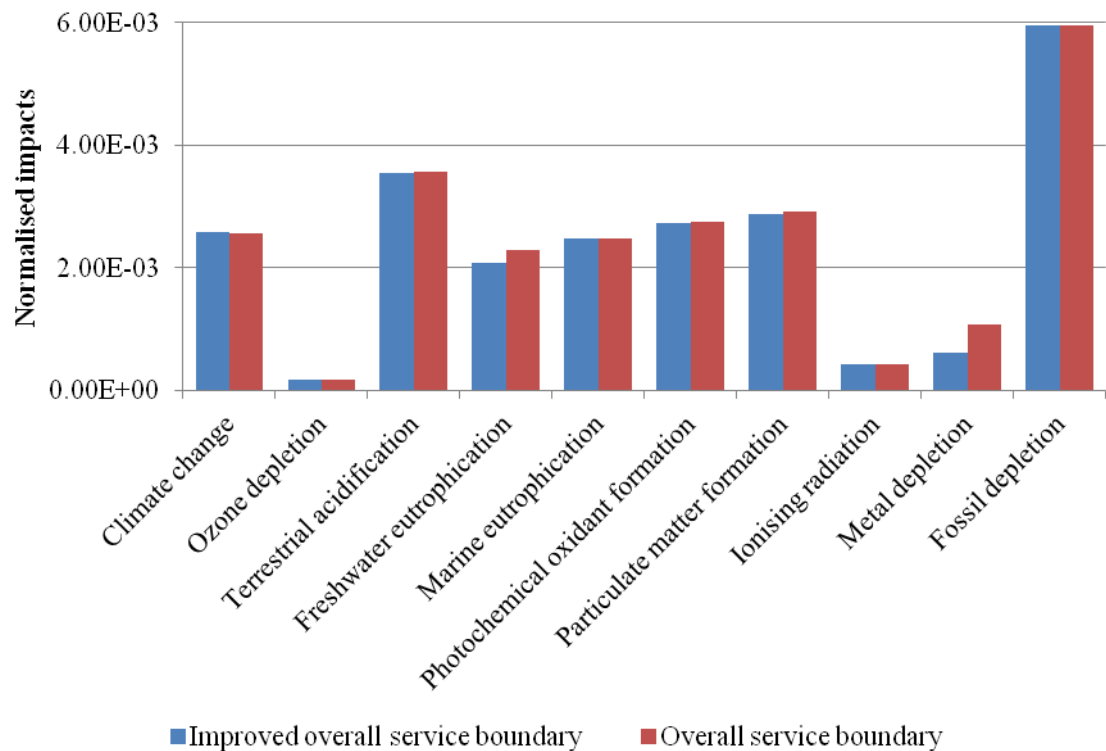


Figure 6.4: Normalised impacts comparing the overall service boundary with applied identified system improvements to the packing company - ReCiPe midpoint (H)

6.1.3. Potential for improvement

The magnitude approach identified that the environmental burden for the overall service could be reduced by ~3% by updating and purchasing *greener* equipment options. The environmental impacts from the service could be reduced further by enabling the computer's power-saving modes however, reductions would be relatively minimal. The assessment highlighted the limited operational control the company has in terms of reducing its overall environmental impacts. The reduction in the service's environmental impacts would be to address transport and this is not operationally feasible.

To address the larger environmental impacts resulting from the service other options would need to be considered to improve environmental stewardship. An option would be for the service provider to offset the emissions for the air travel component of the service. Offsetting emissions however, is controversial receiving much criticism in the literature (Bows & Anderson, 2007; Gössling, *et al.*, 2007; Broderick, 2009; Polonsky, Grau, & Garma, 2010; Fuglestvedt, *et al.*, 2010). The next section presents the application of the magnitude approach to assess environmental aspects in relation to the parameters established for the film company.

6.2. Film company

This section presents the impact assessment results from assessing the environmental aspects for filming and producing a documentary in relation to the temporal measurement of one minute. The

results presented in this section first, are characterised, to identify the relative contribution the filming and producing a documentary and the waste treatment makes to the impact categories for the overall service (see Appendix E: Table 6-2).

6.2.1. Impact assessments

The characterised results presented in Figure 6.5 identified the service of filming and producing a documentary dominating 83% of the impact categories. The waste's main contribution was to the impact categories freshwater ecotoxicity (~63%), marine ecotoxicity (~55%) and human toxicity (~52%). The contribution waste makes to the ecotoxicities categories shows the impact of its emissions on aquatic ecosystems and human toxicity the impact on human health; which can be attributed to the incineration of the treated waste.

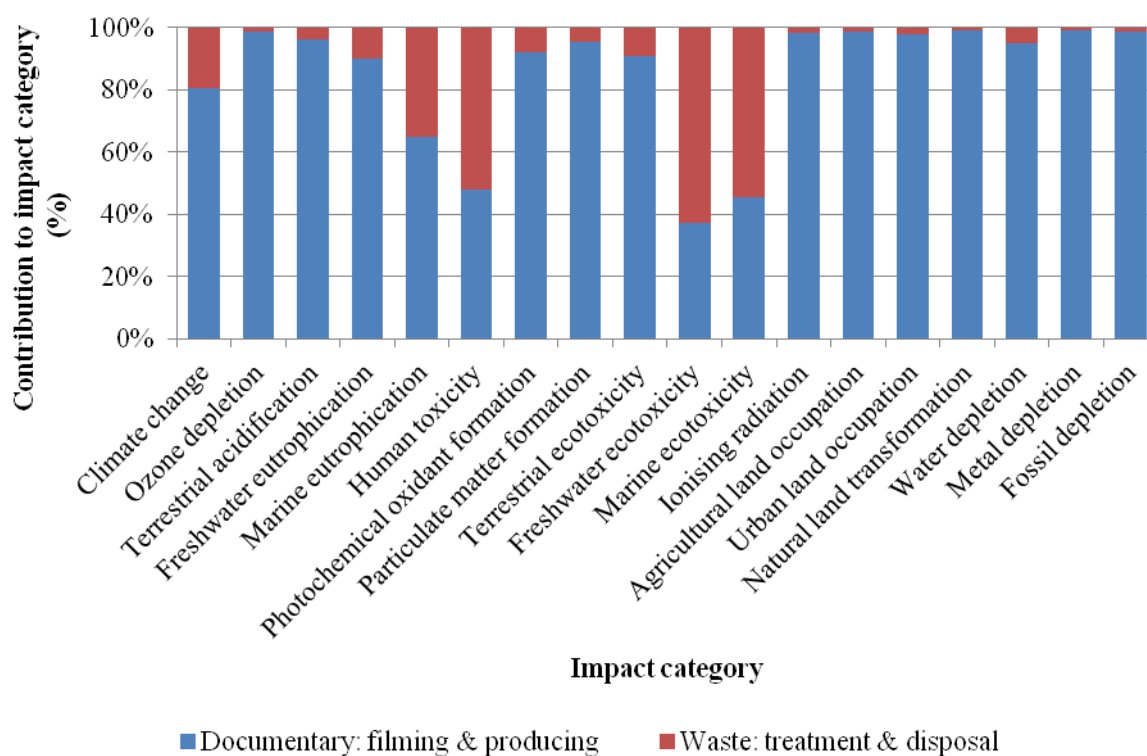


Figure 6.5: Characterised data for filming and producing a documentary - ReCiPe midpoint (H)

The normalisation of the results confirms the significant impacts for the overall service is within the provision of the operational services related to the filming and producing of the documentary (see Appendix E: Table 6-2). This part of the service contributes to ~81% of all impacts the waste, ~19%. The contribution of the waste treatment and disposal is less than a fifth of the overall service boundary therefore, the focus of the study is upon the pre-production, production and post-production stages.

To assist with the prioritising of resources from a company perspective the impact categories were selected based upon characterisation factors that were established (Guinée, 2002) (see Chapter 3, 126

pp.50 & 52), to enable comparative assessments. To identify parts of the service, which contributed to each selected impact category, the data was characterised (see Figure 6.6).

The main findings show the service within the post-production stage was a leading contributor to all impact categories and its three main contributions were to marine eutrophication (~82%); climate change (~78%) and fossil depletion (~72%). The pre-production stage impacts '*significantly*'⁷ on all the impact categories with the largest contribution made to ozone depletion (~29%). The production stage contributed by more than 10% to only one category, relative to the other stages and impact categories and made its largest contribution also to ozone depletion (~15%). The characterised data identified parts of the service, which contributed to each of the selected impact categories. The problem with characterised data is it considers the percentage contribution of each category but cannot determine the significance of the categories in terms of total emissions. To determine the significance of the impact categories and aspects within the service the results were normalised.

⁷ Significantly, in this instance was having a contribution in excess of 10%, relative to the total impact for that particular category.

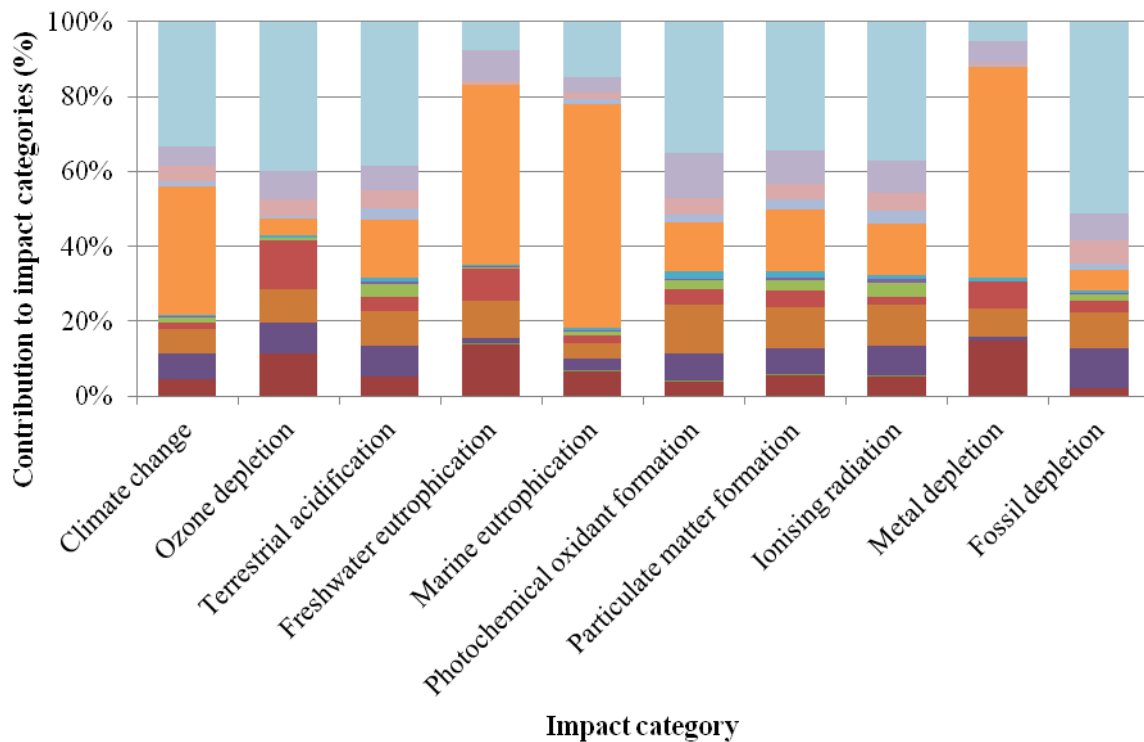


Figure 6.6: Characterised data showing the contribution made to each selected impact category in filming and producing a documentary - ReCiPe midpoint (H)

The results from normalisation are illustrated in Figure 6.7, which identified the significant impact categories and aspects pertinent to each stage. The key issues identified from the normalised data were as follows:

- The majority of environmental impacts resided within the post-production stage of the service which contributed ~71% of all impacts; pre-production ~22% and production ~7%
- The equipment used by the service contributed to ~41% of the environmental burden, collectively the largest
- The service's three largest contributions are to fossil depletion (~23%); metal depletion (~17%) and climate change (~16%)
- In the pre-production stage the localised hotspot came from the meeting of clients off-sites and the transport used; the three main impacts that this activity contributed to was fossil

depletion (~26%); metal depletion and freshwater eutrophication both with ~14% and climate change ~12%

- In the production stage, the filming equipment contributes to ~62% of all impacts most notably to metal depletion (28%); freshwater eutrophication (24%) and fossil depletion (17%)
- The equipment of particular note within the production stage was the film used to shoot the documentary; the three main categories the film contributed to were identified as fossil depletion (36%); freshwater eutrophication (22%) and climate change (10%)
- In the post-production stage the largest environmental impact was solely provided by heating which contributed ~23% of impacts within the stage however, equipment used in the editing process collectively, contributed to ~41% of all impacts, most notably to metal depletion (~33%); freshwater eutrophication (~20%) and climate change (~19%)

The key issues are identified within the system; however, their relative contribution needed to be ascertained to ensure resources can be targeted. The stage approach was maintained and the relative contributions of the processes and materials in respect of these approaches were identified. It is recognised that the hotspot is within the post-production stage. To focus however, on this stage solely for a small system would obscure those modifications that can be quickly implemented within a short-time frame, that are low investment and can be undertaken with minimal preparation or effort that would be of benefit. To ensure that a focus on environmental relevance is maintained the reduction in impact categories was retained. The results are presented in Table 6.2. The *immediacy of the resources needed to affect change* column, refers to the outlay in relation to time, costs, preparations or effort.

In the pre-production stage, the main issue was confirmed as being transport fuelled by petrol, which contributed to 37% of all the impacts. This aspect within the system is controlled directly by the company and alternative fuels, for instance, LPG could be sought to reduce the impacts and environmental burdens. The capital outlay for this option however, means this is not immediately viable for a small company and would be a considered choice in future purchases of vehicles. In the production stage, energy used to operate and recharge filming and office equipment contributed to 25% of impacts. In the post-production stage, the use of gas to heat the studio in the editing processes was the main impact and contributed 23%. The company has direct control over its energy use and can use behavioural cues to alter established patterns. This will need investment and time, therefore, is a long-term objective to tackling and reducing the environmental impacts. An immediate, low investment, with minimal preparation and effort strategy would be to consider the use of materials i.e. equipment.

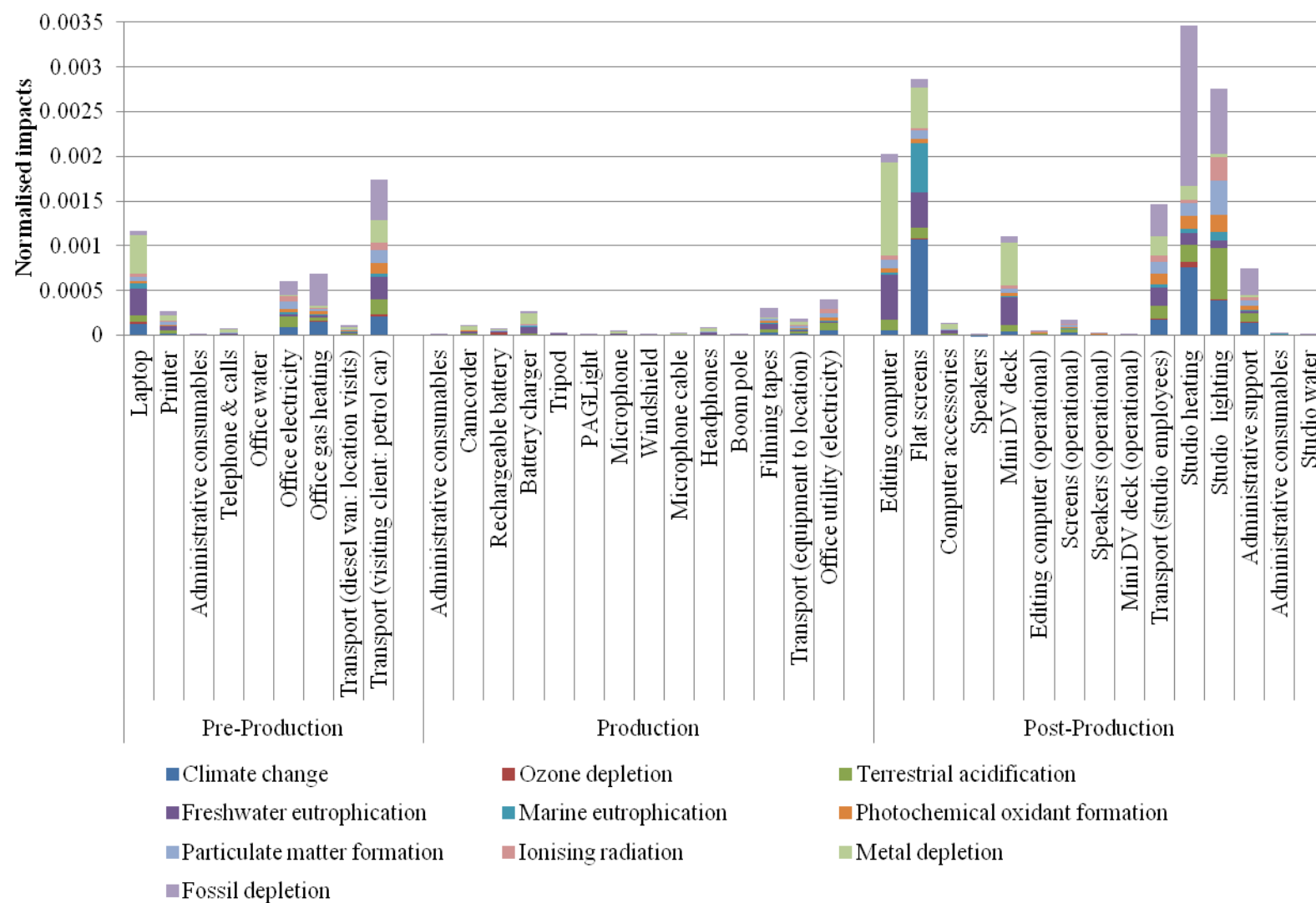


Figure 6.7: Normalised impacts, resulting from, the service to film and produce one minute of documentary film - ReCiPe midpoint (H)

Table 6.2: Relative contribution using normalised impacts for aspects identified as contributing to overall impacts that were =>10% to film and produce one minute of documentary film - ReCiPe midpoint (H)

Pre-Production			
Aspects	Immediacy of resources needed to affect change	Total impacts (People Emissions Equivalents)	Relative contribution (%)
Transport (<i>petrol car</i>)	Not immediate	1.74E-03	37
Laptop (<i>equipment</i>)	Not immediate	1.17E-03	25
Office heating	Not immediate	6.93E-04	15
Office electricity	Not immediate	6.03E-04	13
Materials (<i>total value of equipment that individually contributed < 10%</i>)	Varies	3.39E-04	7
Transport (<i>total value of travel that contributed < 10%</i>)	Varies	1.13E-04	2
Others (<i>administrative consumables / support</i>)	Varies	4.81E-07	1
Totals		~4.66E-03	~100
Production			
Operational electricity	Not immediate	3.98E-04	25
Filming tapes (<i>equipment</i>)	Immediate	3.06E-04	20
Battery charger (<i>equipment</i>)	Not immediate	2.65E-04	17
Transport (<i>van</i>)	Not immediate	1.83E-04	12
Materials (<i>total value of equipment that individually contributed < 10%</i>)	Varies	3.83E-04	25
Others (<i>administrative consumables / support</i>)	Varies	1.30E-06	1
Totals		~1.54E-03	~100
Post-Production			
Studio heating	Not immediate	3.46E-03	23
Editing Screen	Immediate	2.87E-03	19
Studio electricity (equipment & lighting)	Not immediate	3.02E-03	20
Editing computer	Not immediate	2.03E-03	14
Transport (<i>employees</i>)	Not immediate	1.47E-03	10
Materials (<i>total value of equipment that individually contributed < 10%</i>)	Varies	1.25E-03	8
Others (<i>administrative consumables/ support</i>)	Varies	7.88E-04	5
Totals		~1.49E-02	~100

(in the process of rounding values totals do not always compute to 100)

In the production stage, filming tapes contributes to 20% of impacts. The average number of tapes used for four days of documentary filming equates to approximately 5 hours of filming per day, which uses approximately 5 tapes per day. Twenty tapes are used to film an eight-minute documentary. The tapes can be used on short play or long play. The observed behaviour is that short play is used as opposed to long play. To reduce the environmental impact, the option would be to use long play as this would extent the filming time for one tape from 60 minutes to 90 minutes. The number of tapes used for an eight-minute documentary could be reduced from 20 tapes to approximately 12 tapes; this would reduce the number of tapes from five tapes a day to approximately three tapes a day; which equates to a 60% reduction in tape use. The bulk purchase of these tapes and their relative cheapness means that the incentive to do this would not be

financially led however, in terms of an immediate reduction in the environmental burden of the service this would be of benefit.

The post-production stage, involves working in the editing suite *cutting and splicing* together, the filmed material into a *story*. This part of the work is studio bound and explains the nature of the environmental impacts within this stage. The relative contribution of the energy consumption combined contributes to 43% of the total impacts. However, as mentioned previously measures that can assist in the reduction of the environmental burden in relation to this aspect would be part of a long-term sustainability training initiative. To obtain an immediate reduction in the environmental burden for this stage the two screens used in the editing process merit consideration. The 17" screens are used to view the film at different stages of the editing process and contribute 19% to the total impacts. The suggestion is to use only one screen, which is feasible as it still allows the editor to work and edit effectively without compromising the quality of the service.

The areas where the company could immediately reduce their environmental burden within the specific stages and for the overall system resulted in three different scenarios being created. In the next section, the scenarios developed to reduce the service's environmental burden that could be easily implemented with minimal preparation and effort is presented.

6.2.2. Interpretation

This section of the study shows the findings, discusses the key issues and determines the areas that can be improved to reduce the service's environmental impacts. Three scenarios were developed and each were assessed using ReCiPe (midpoint) to quantify the effect on resource consumption and emissions relative to the base case for shooting and producing one minute of documentary film. A selected number of impact categories were included in the scenario assessment but were consistent with the previous analysis.

In the production stage, the key hotspot was the film used to shoot the documentary. The three main impact categories that the tapes contributed to were fossil depletion (~36%); freshwater eutrophication (~22%) and climate change (~10%). The flat screens were identified as having an immediate effect on the environmental burden in the post-production stage, contributing to climate change (~38%), marine eutrophication (~19%) and metal depletion (~16%).

Accordingly, the first scenario (A) developed for the production phase resulted in the use of film reduced by 60% to represent the use of the long play (LP) option. A second scenario (B) was modelled to reduce the impacts within the post- production stage. In the second scenario (B), the screens used in the editing process was reduced by 50% and instead of two screens and their energy consumption, the impact of one screen and its energy use was modelled. In a third scenario (C) all

the modelled parameters were put in the context of the overall service boundary. The key findings from the scenario analysis are detailed in Table 6.3 and illustrated in Figure 6.8 where the data was normalised and a comparison of the different scenarios relative to the base case is presented.

Table 6.3: Key findings from the scenarios to film and produce one minute of documentary film

Scenario	Base case	Changes in the base case	Percentage changes to the main impact categories from changes made to the base case
A	Production: Film	Reduced tape use by 60% by altering the mode of operation to LP	Decrease in fossil depletion by ~15%; freshwater eutrophication by ~10% and climate change by ~9%
B	Post Production: Editing 17" screens	Reduced numbers of screens by 50% and the power used by 1.23kWh	Decrease in marine eutrophication by ~34%; climate change by ~21% and freshwater eutrophication by ~12%
C	Overall service boundary	Application and input of scenarios A & B to the overall service boundary	Decrease in marine eutrophication by ~18%; climate change by ~13% and freshwater eutrophication by ~8%

In the production stage, the reduction of film was seen as a minimal effort and quickly implemented strategy in terms of mitigating the environmental burden in this part of the model. The adjustment of the camera so that the filming is undertaken using long play instead of short play increases filming time on the tape by 30 minutes and thereby reduces the amount of film used. The implementation of this option would result in the environmental burden being reduced for all impact categories and overall for this stage by ~8%. In the post-production phase, the use of only one screen for editing purposes was identified as a low investment initiative that would reduce environmental impacts. All the selected impact categories that were analysed resulted in a reduction in impacts (see Table 8.3). Subsequently, the use of one screen instead of two and the accorded reduction in energy resulted in the environmental burden within that stage being reduced by ~10% (see Figure 6.8).

To determine the environmental impacts in relation to the overall service boundary a model was developed (scenario C) using the new *improvement* initiatives and incorporating the waste scenario and treatment model (see Figure 6.8). The findings show in relation to the base case that for the overall system with the modifications towards an environmentally responsive system there was a reduction in all of the selected impact categories (see Table 6.3 for the three notable reductions). The application of these scenarios thereby resulted in a decrease in service's overall impacts by ~7% and in terms of GHG emissions by ~13%, from 48kgCO_{2e} to 42kgCO_{2e}.

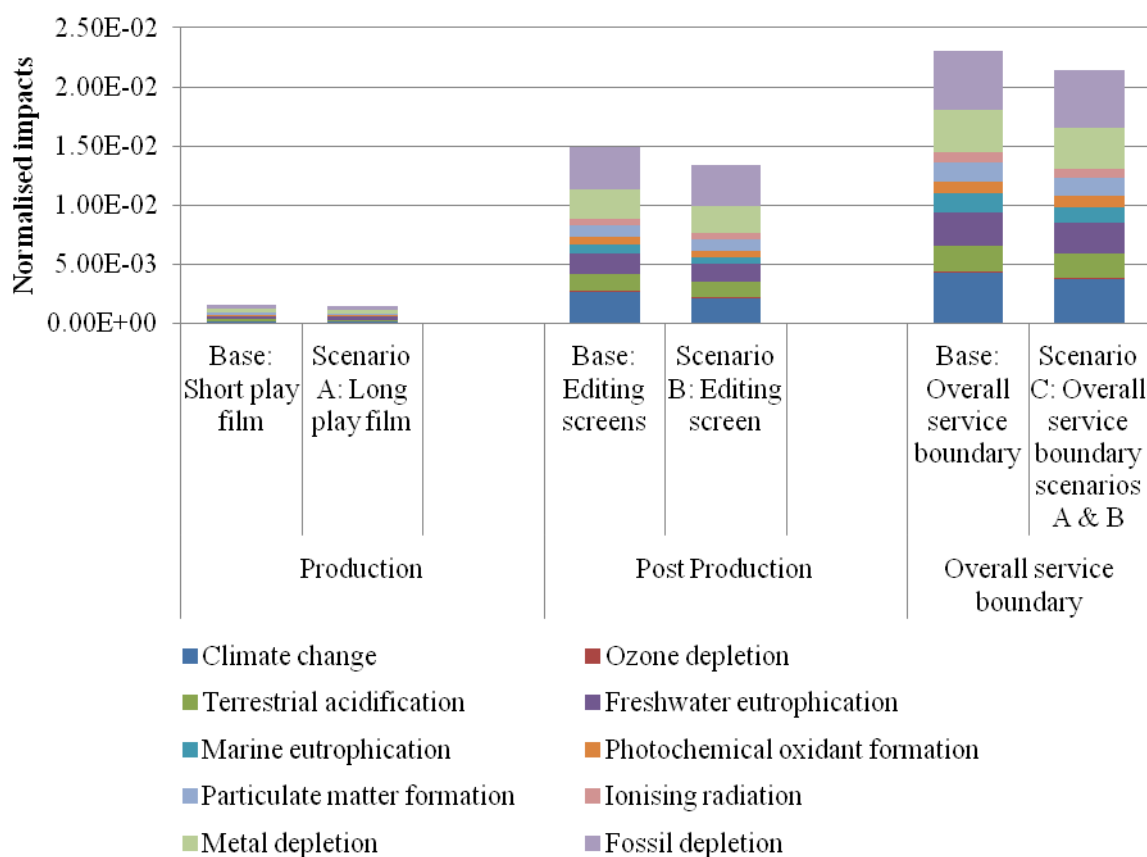


Figure 6.8: Normalised impacts comparing the scenario findings with the base cases for the film company - ReCiPe midpoint (H)

6.2.3. Potential for improvement

The key findings from the scenarios identified areas where the environmental load can be mitigated. The operational option to use LP as opposed to SP and the use of one editing screen will reduce the potential impacts of developing, shooting, and producing a documentary film. These recommendations are made because not only will they reduce the overall environmental burden of the system but also they are feasible for a small company.

To mitigate the impact of transport green fuel options could be considered, for instance LPG or biodiesel produced from waste oil. These options would reduce emissions however; the costs and time employed converting an established petrol vehicle into accommodating this fuel and the inconvenience and limited re-fuelling provisions⁸ excludes many alternative green options that could reduce environmental impacts (see Chapter 6). This highlights the general inaccessibility of new *green* initiatives for smaller companies. In addition, the findings reflect the potential dominance of embodied energy from equipment and its influence in the service. Further research is however, needed to determine if this is specific to companies generally or only particular to this

⁸ Only 8% of fuelling stations in the UK cater for alternative '*green*' fuel options (Renshaw, 2012).

type of industry. The next section of this chapter applies the approach and delivers the analysis for the ODL company.

6.3. Online distance learning company

To assess the environmental aspects of the ODL company and identify which aspects of the service as per functional unit contributed to each impact category, the data was assessed using ReCiPe and characterised and normalised as appropriate (see Chapter 5, p.108).

6.3.1. Impact assessments

The main findings from the characterised data, using ReCiPe (midpoint) (see Figure 6.9) can be summarised as follows:

- Computer equipment, which included desk tops, monitors and printers contributed in excess of 10% to every impact category, and makes the largest contribution to metal depletion (~91%)
- Kitchen equipment & office appliances, emails, and water use contributed negligibly to their respective impacts categories with values of less than 1%
- Travel, waste, telephone calls, the network and electric heating contributed less than 5% to their respective impact categories
- Furniture, which included desks and chairs, contributed in excess of 5% for 28% of their respective impact categories with the largest contribution to agricultural land occupation (~60%)
- Gas heating contributed in excess of 5% for 33% of their respective impact categories; the largest contribution to ozone depletion (~46%)
- Electricity used to power equipment, appliances and lighting contributed in excess of 5% for 39% of their respective impact categories, both aspects made their largest contribution to ionising radiation; powering equipment and appliances contributing ~25% and for lighting ~17% respectively
- Computer accessories, which included mice and keyboards in the model, contributed in excess of a 5% burden to 11% of their respective impact categories, making the largest contribution to freshwater ecotoxicity (~6%)
- Paper, contributed in excess of a 5% burden to 6% of its respective impact categories, making the largest contribution to agricultural land occupation (~12%)

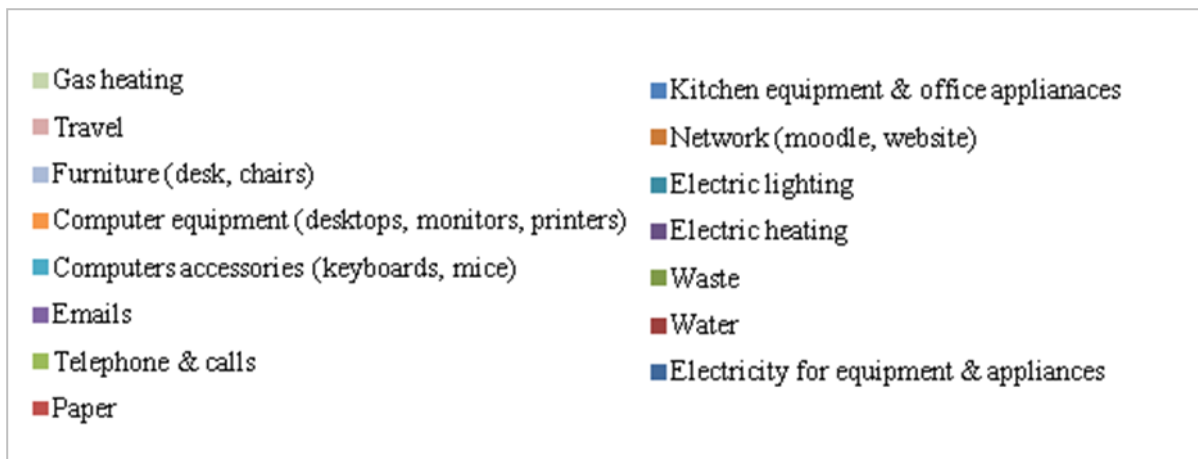
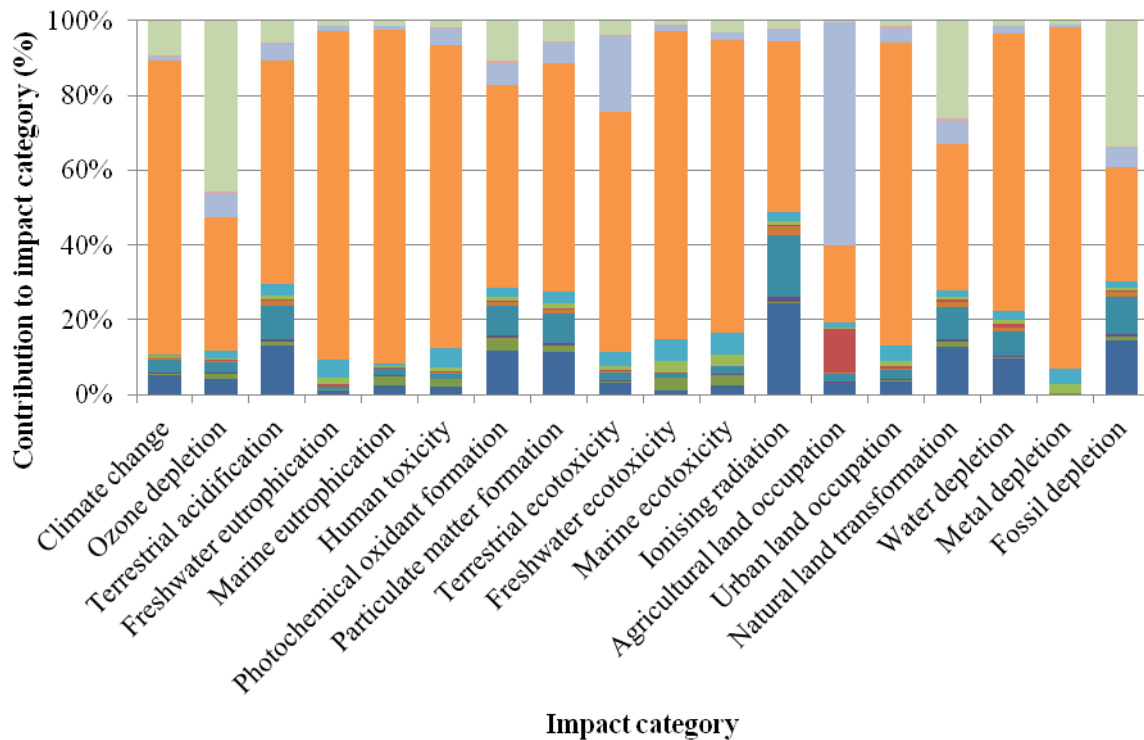


Figure 6.9: Characterised data for the ODL company - ReCiPe midpoint (H)

The characterised results identified the relative contribution for different aspects of the service however, to determine the significant impact categories and the order of magnitude as to where the environmental problems are generated the data was further processed and normalised (see Figure 6.10). In this process, the impacts categories were selected based upon the premise afforded to the preceding case studies.

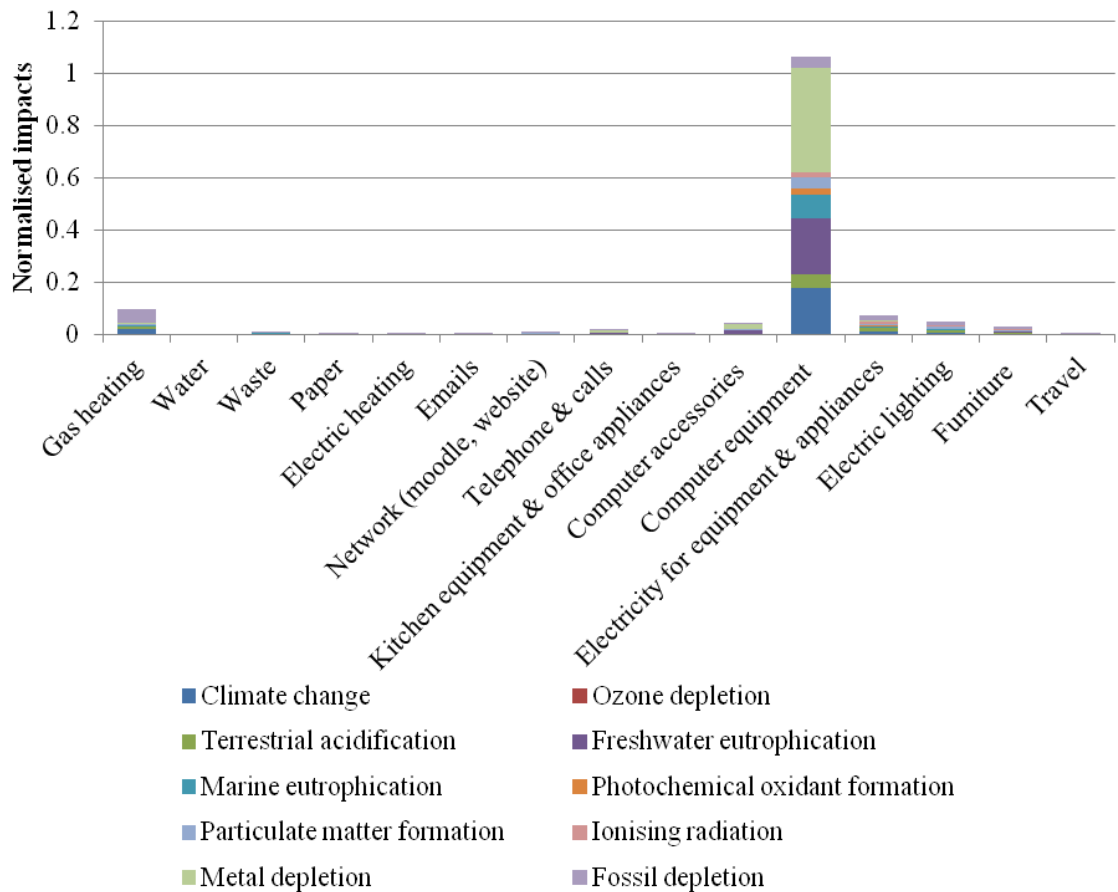


Figure 6.10: Normalised impacts for the ODL company - ReCiPe midpoint (H)

The normalised findings confirms that the computer equipment causes a significant environmental burden and contributes to ~76% of the overall burden; gas heating, ~7% and the electricity used to power equipment and appliances, ~5%. The findings show the service contributes ~31% to metal depletion, ~17% to freshwater eutrophication and ~16% to climate change.

The data was further analysed using ReCiPe at midpoint level with a hierarchist (H) perspective to identify the system where the equipment and heating were contributing to the greatest impact damage. The use of computer equipment is recognised in the home based and local based activities and gas heating most notably in the home based activity. The home based system comprises of the activities for the student and tutor and the location of the aspects within the system boundary is needed as this can potentially influence the recommendations made to reduce the environmental impacts.

The data from the home and local based activities was characterised to identify aspects of the service, which contributed to each impact category. The home based activities specific to the student dominated all impact categories; contributing in excess of 90% for all their respective impact categories. The home based activities relevant to the tutor contributed an environmental burden of less than 5% to all their respective impact categories; making the largest contribution to

fossil depletion (~2%). The local office based activities, contributed burdens of less than 5% to their respective impact categories, making the largest contribution most notably to photochemical oxidant formation (~3%). To ascertain the significant relative impacts within the systems, the data was normalised (see Figure 6.11).

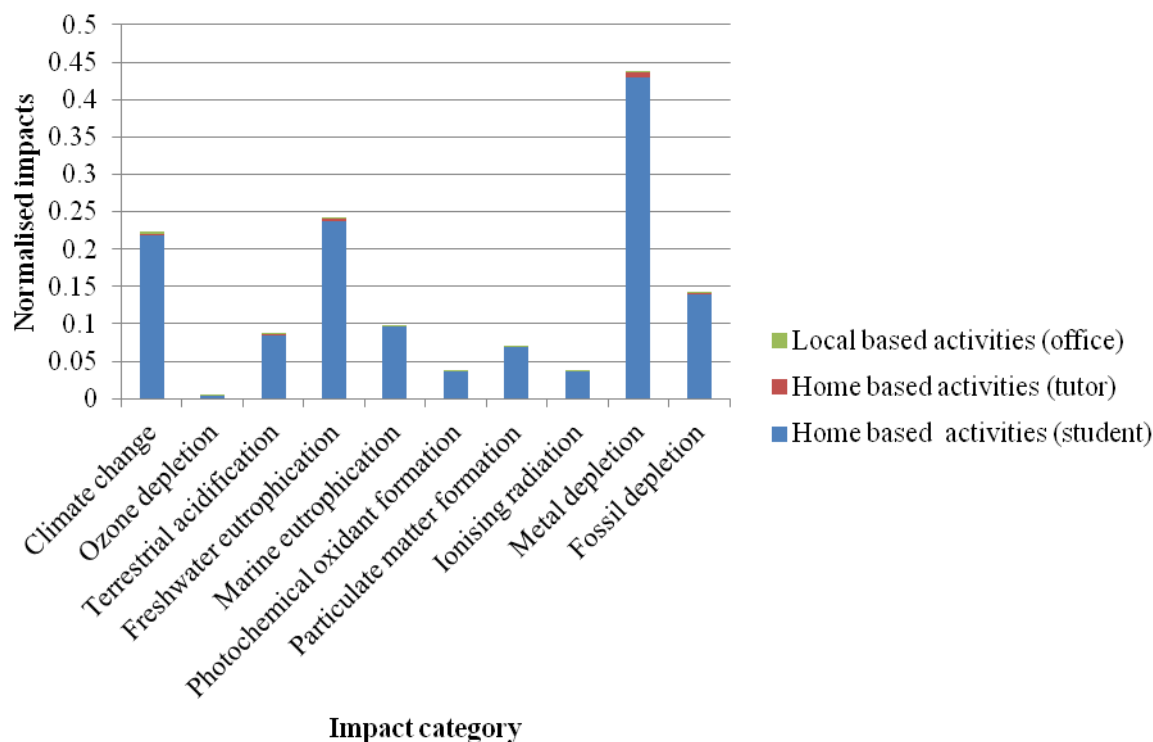


Figure 6.11: Normalised impacts for local and home based activities - ReCiPe midpoint (H)

The normalising of the data confirmed that the hotspot was located within the home based activities pertinent to the student. (see Figure 6.11), which contributed to ~98% of the overall impacts. The home based system modelled on the activities relevant to the student and course tutor within the home show the environmental burden from the tutor's activities resulting in ~1% of overall impacts and the local based activities, ~1%. The significant impacts within the student environment were identified as metal depletion (~32%), freshwater eutrophication (~18%) and climate change (~16%). The significant impact categories and home based activities relevant to the student acknowledged by the normalisation of the data was used to highlight the percentage contribution from aspects that was equal to or greater than 5% (see Table 6.4).

The largest contributor to each of the identified significant impact categories for the home based student activities was the components, processes and materials used to manufacture computer equipment. The desktop computer was highlighted as the largest contributor to both the metal depleted category and freshwater eutrophication with 74% and 64% respectively. The use of metals in the construction of computer equipment is reflected in the former category.

The computer equipment; in the form of a desk top computer and LCD monitor contributed ~74% and ~15% respectively to the metal depletion impact category and accounted for 273kg Fe eq. from a total of 307kg Fe eq. The impact on freshwater eutrophication was caused by the emissions of waterborne nutrients most notably phosphate and phosphorous. The major waterborne emission produced by the desktop computer was phosphate and those particular to LCD monitors were phosphorous. The main contributor to climate change was the LCD monitor that contributed ~71% to the impact category. The main GHGs that contributed to the impact category were carbon dioxide (fossil), methane (fossil), nitrogen fluoride and sulphur hexafluoride. The LCD monitor was the main contributor to the production of nitrogen fluoride and contributed ~93% to sulphur hexafluoride emissions.

Table: 6.4: Contribution from aspects to significant impact categories highlighted as hotspots; within the home based activities (*student model with percentage contributions =>5%*)

Significant impact categories	Aspects	Units (kg per unit indicator equivalents)	Contribution from aspects to impact category (%)
Metal depletion	Desk-top computer	227kg Fe eq.	74
	LCD monitor	46kg Fe eq.	15
Immediate value or contribution	-	273kg Fe eq.	89
Remaining substances value or contribution	Various (individually <5%)	34kg Fe eq.	11
Totals		~307kg Fe eq.	100
Freshwater eutrophication	Desk top computer	0.04kg P eq.	64
	LCD monitor	0.01kg P eq.	24
Immediate substances value or contribution	-	0.05kg P eq.	88
Remaining substances value or contribution	Various (individually <5%)	Collectively < 0.01 kg P eq.	12
Totals		~0.06kg P eq.	100
Climate change	Desk top computer	193kg CO ₂ eq.	8
	LCD monitor	1745kg CO ₂ eq.	71
	Electricity to run computer, monitor and printer	127kg CO ₂ eq.	5
	Gas for space heating	234kg CO ₂ eq.	10
Immediate substances value or contribution	-	2299kg CO ₂ eq.	94
Remaining substances value or contribution	(individually <5%)	149kg CO ₂ eq.	6
Totals		~2448kg CO₂ eq.	100

The service provider has no direct influence on or over the student's activities; therefore, suggestions and recommendations to reduce environmental impacts are compromised and limited. The service provider can influence the tutor's activities because of their considered position as a supplier however, the home base and the contracted self-employed status of the tutor limits the influence of the company although it is greater than that for the student. The service provider however, has more influence and direct operational control over the local, regional and network

based activities. The next stage in the analysis therefore, was to consider the localised activities, and the aspects that included; processes, components and materials modelled for the local, regional and network based systems; to determine the environmental impacts and significant hotspots. The data was initially characterised to identify the extent to which the systems contributed to each selected impact category (see Figure 6.12).

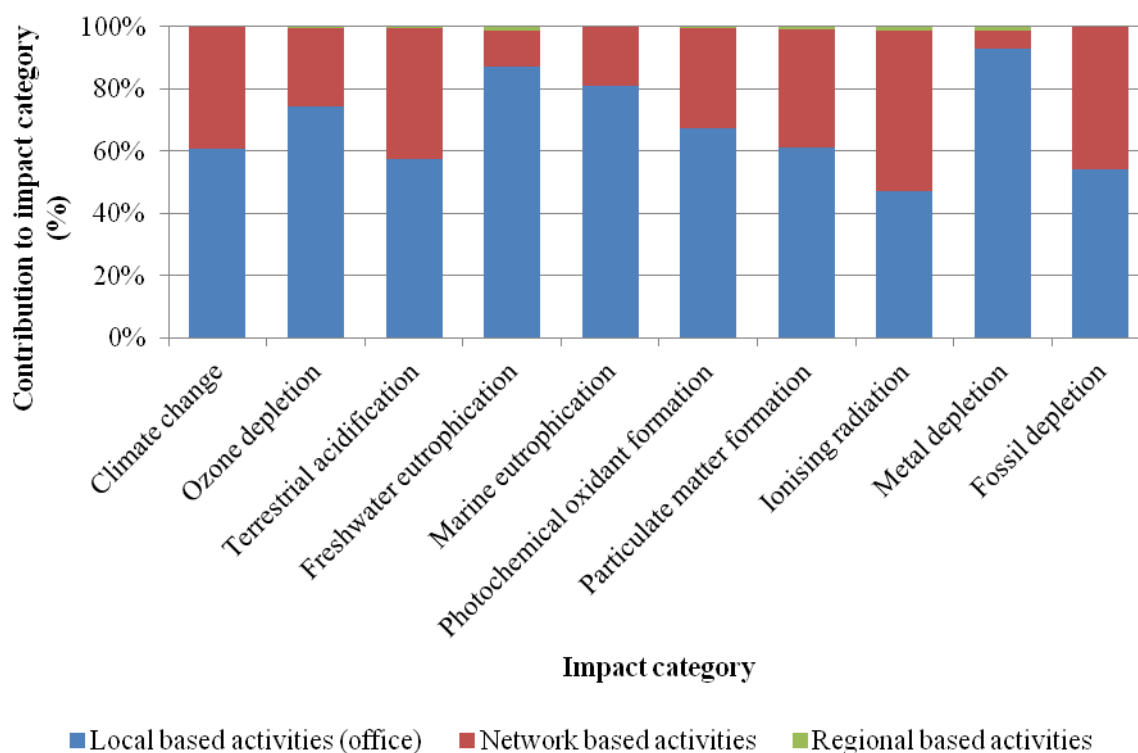


Figure: 6.12: Characterised data for local, regional and network based activities - ReCiPe midpoint (H)

The Figure 6.12 illustrates the dominance of the local based system in their contribution to all impact categories. The local based system exceeded a 5% contribution in all impact categories, the network-system in 90% of the selected impact categories and the regional, in none of the impact categories. The regional based and local systems largest contribution was to metal depletion with ~1% and ~93% respectively and the network-activities to ionising radiation, ~52%.

The activities relevant to the local and network-based systems were therefore, of interest. The data was further processed and normalised to determine the significant impact categories within these systems with the largest relative impacts (see Figure 6.13). Collectively, the three significant impacts identified were fossil depletion; climate change and terrestrial acidification (see Figure 6.13.). The local based activities contributed the largest environmental burden and thereby merited further exploration.

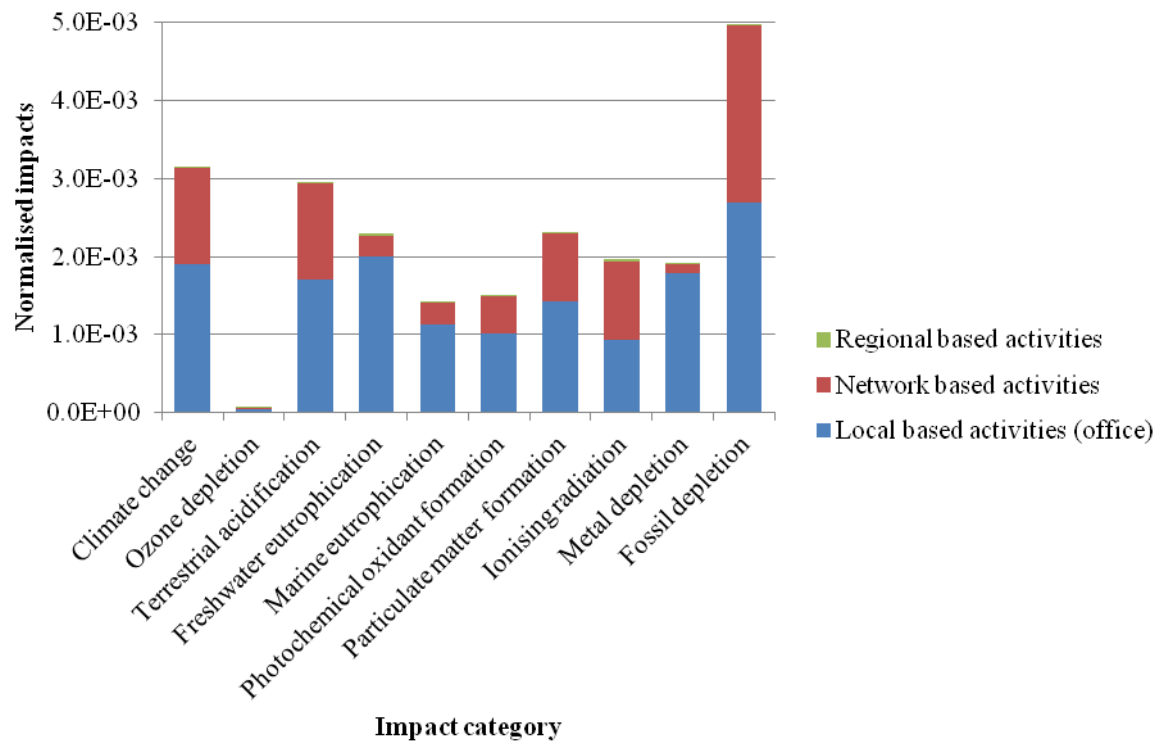


Figure 6.13: Normalised impacts for local, network and regional based activities - ReCiPe midpoint (H)

The analysis of the local based activities was undertaken using ReCiPe at midpoint level characterised to identify parts of the system that contributed to each impact category. The data was then normalisation to ascertain where the significant impacts and emissions were located within the system. The three key impact categories were identified as fossil depletion, freshwater eutrophication, and climate change (See Figure: 6.14). The aspects which contributed to each of these categories, was investigated further (see Table 6.5) in relation to a relative contribution that was $\geq 5\%$ for the identified three largest impact categories.

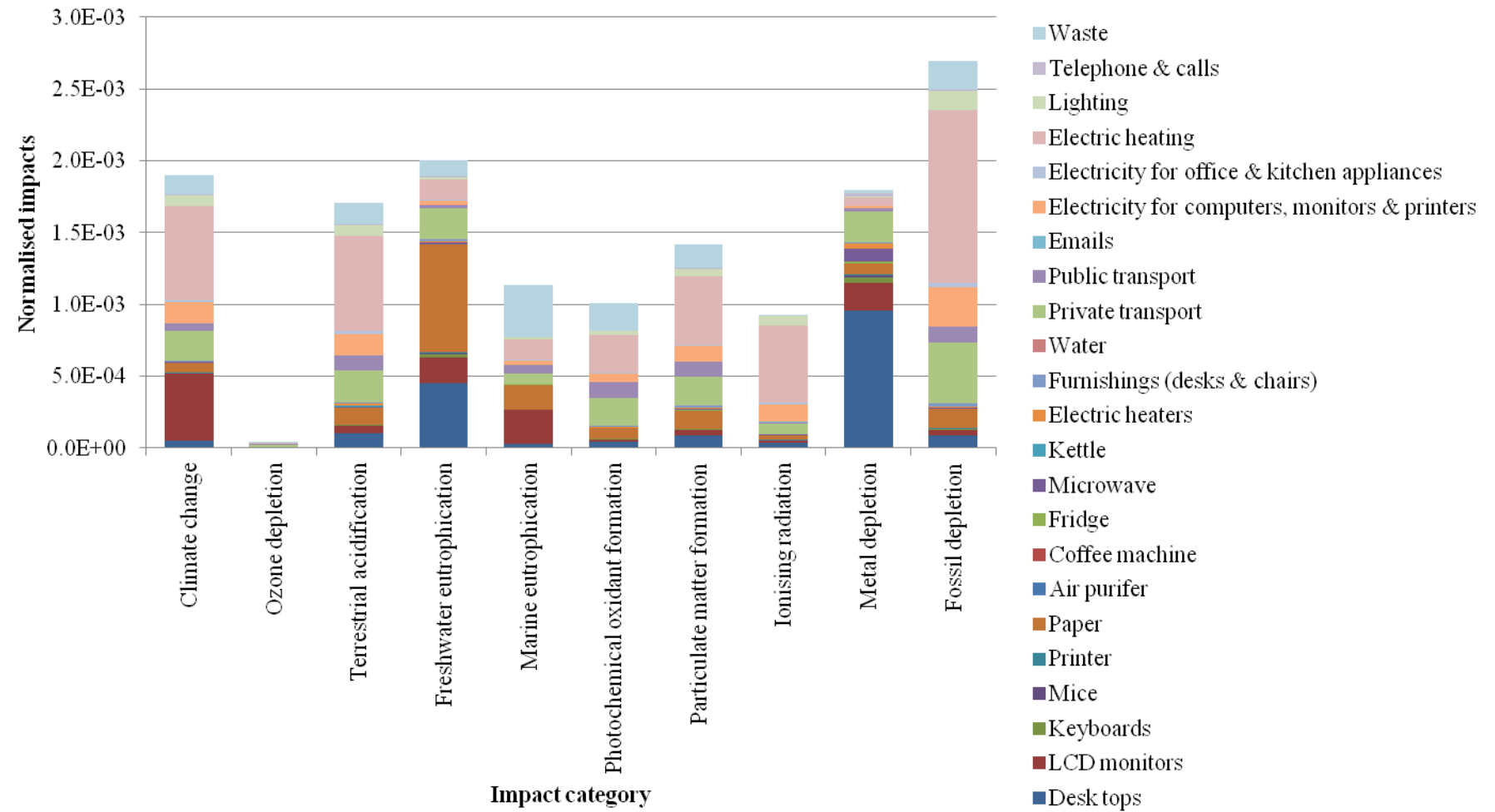


Figure 6.14: Normalised impacts for the aspects modelled, relating to local based activities - ReCiPe midpoint (H)

Table: 6.5: Contribution from aspects to significant impact categories highlighted as hotspots; within the local based activities (*contributions =>5%*)

Significant impact categories	Aspects	Unit (kg per unit indicator equivalents)	Contribution from the aspect to the impact category (%)
<i>Fossil depletion</i>	Electric heating	2.28kg oil eq.	45
	Private transport: petrol passenger cars	0.81kg oil eq.	16
	Electricity used to run computers monitors and printer	0.52kg oil eq.	10
	Waste	0.38kg oil eq.	7
	Electric lighting	0.25kg oil eq.	5
	Paper	0.25kg oil eq.	5
	<i>Immediate processes</i>	~4.49kg oil eq.	~88
<i>Remaining substances</i>		~0.63kg oil eq.	~12
<i>Total for all process</i>		~5.12kg oil eq.	~100
<i>Freshwater eutrophication</i>	Paper	0.0002kg P eq	40
	Desktop computers	0.0001kg P eq	20
	Private transport: petrol passenger cars	0.00005kg P eq	10
	LCD monitors	0.00004kg P eq	8
	Electric heating	0.00003kg P eq	6
<i>Immediate substances</i>		~0.00042kg P eq	~84
<i>Remaining substances</i>		~0.00008kg P eq	~16
<i>Total for all processes</i>		~0.0005kg P eq	~100
<i>Climate change</i>	Electric heating	7.34kg CO ₂ eq	34
	LCD monitors	5.23kg CO ₂ eq	25
	Private transport: petrol passenger cars	2.32kg CO ₂ eq	11
	Electricity used to run computers monitors and printer	1.67kg CO ₂ eq	8
	Waste	1.47kg CO ₂ eq	7
<i>Immediate substances</i>		~18.04kg CO ₂ eq.	~85
<i>Remaining substances</i>		~3.30kg CO ₂ eq	~15
<i>Total for all processes</i>		~21.34kg CO ₂ eq.	~100

The main contributor to fossil depletion was the electricity used to heat, light and power the computers, monitors and printer in the office environment; that accounted for ~60% of the total impacts within this category. The office heating which is electric powered contributed to ~45% of the impact category with a total of 2.28kg of oil eq. being consumed most notably natural gas and hard coal used in the grid mix.

The use of petrol to power transport contributed to 16% of the impacts within this category. The transport consumed ~0.81kg of oil eq. which can be attributed to the use of crude oil. The remaining components, processes and materials that contributed to ~12% of the impact category was the contribution made by waste and paper accounting for 0.38 and 0.25kg of oil eq. respectively.

Freshwater eutrophication was recognised as a potential issue within the local based system. The main source of water bourne emissions was from the use of paper attributed to the hardcopies of invoices and student coursework needed for grade accreditations by examinations boards to ensure consistency in grading. The production and use of paper by the office contributed two-fifths of all emissions for this category.

In terms of climate change a total of ~21kg CO₂ eq. is released by the service activities for the local based system. The emissions composed predominately of the GHGs, carbon dioxide and methane from fossil fuels and nitrogen flouride. The office heating accounted for ~7.3kg CO₂ eq.; contributing a third of the emissions within the impact category. The production of the LCD monitors contributed ~25% to the overall impact category and transport ~11%; which accounted for ~5.2 and ~2.3kg CO₂ eq., respectively.

The main findings from this section of the study using ReCiPe (midpoint) can be summarised as follows:

- The hotspot was located within the home based system which contributed to ~98% of all impacts for the service, most notably from student
- Student home based activities significantly contributed to metal depletion, freshwater eutrophication and climate change
- The main material contributors to each of the identified impact categories for the home based system was the desktop computer for metal depletion (~74%) and freshwater eutrophication (~64%) and the LCD monitor for climate change (~71%)
- Operationally controlled systems by the service, local based, regional and network activities, identified local based activities contributing to all impact categories, and having the largest relative impact (~65%)
- The local based activities largest contributions to impacts were notably to fossil depletion (~18%), freshwater eutrophication (~14%) and climate change (~13%)
- The three key contributors to the significant impact categories identified for the local based system are broadly related to heating, transport and equipment

The main processes, materials and components that contributed to the key impacts were the focus of the development for three scenarios to mitigate the impacts resulting from the service. The next section discusses the development of the scenarios based upon the issues highlighted from the assessment.

6.3.2. Interpretation

Three scenarios, A, B and C were developed based upon the key issues identified to show how the hotspots can be potentially mitigated and data assessed for consistency and comparability with ReCiPe midpoint (H) (Europe).

6.3.2.1. Scenario development

The development of scenario A was undertaken to mitigate the identified hotspots within the home-based system that was specific to the student's activities and to validate the modelled parameters based upon the course guidelines. To validate the modelled data parameters primary data was obtained from the students undertaking the ODL HND Level 5 Business Management course from an online survey added as a '*pop-up*' placed in Moodle.

Forty-two HND students completed the online survey. The survey consisted of ten questions which covered the number of hours spent studying per week on the course; space heating and lighting requirements when studying; the number of hours, the type of computer equipment used and the 'shut-down' procedure.

The results from the online survey were analysed and based upon the average responses, the modal or median values as appropriate, data parameters for one HND student was developed. The resulting data parameters was for a student who studied at home for 15 hours per week on a 60W laptop that was shut-down after the study period, The study space was heated by gas for 7.5 hours per week and a 60W traditional light bulb provided the lighting source for the area for 15 hours per week.

The second scenario (B) was developed that reflected the immediate operational control the company felt they had over their components, processes and materials within the systems local, regional and network based. Accordingly, electric heating, transport, paper use and equipment modularity was addressed. A renewable energy option as a scenario alternative to the provision of heating by electricity was not modelled because of the vagaries of funding both at local, regional and national levels, which limits its viability as an option for SMEs generally. The third scenario (C) was developed to determine the effects of the identified environmentally favourable alternatives in relation to the provision of the overall service.

6.3.2.2. Scenario interpretation

The data for scenario A is illustrated graphically in Figure 6.15 and highlights a number of key issues in respect to the actual impacts the activities have on the categories and the modelling discrepancies between recommended guidance and rubric course guidelines. In Figure 6.15, the base case denotes the model data as developed from recommended study guidelines and the

scenario the actual data provided by the students. The data was characterised and normalised, with Figure 6.15 showing the impact categories for the student home based systems, both for the base case and scenario A.

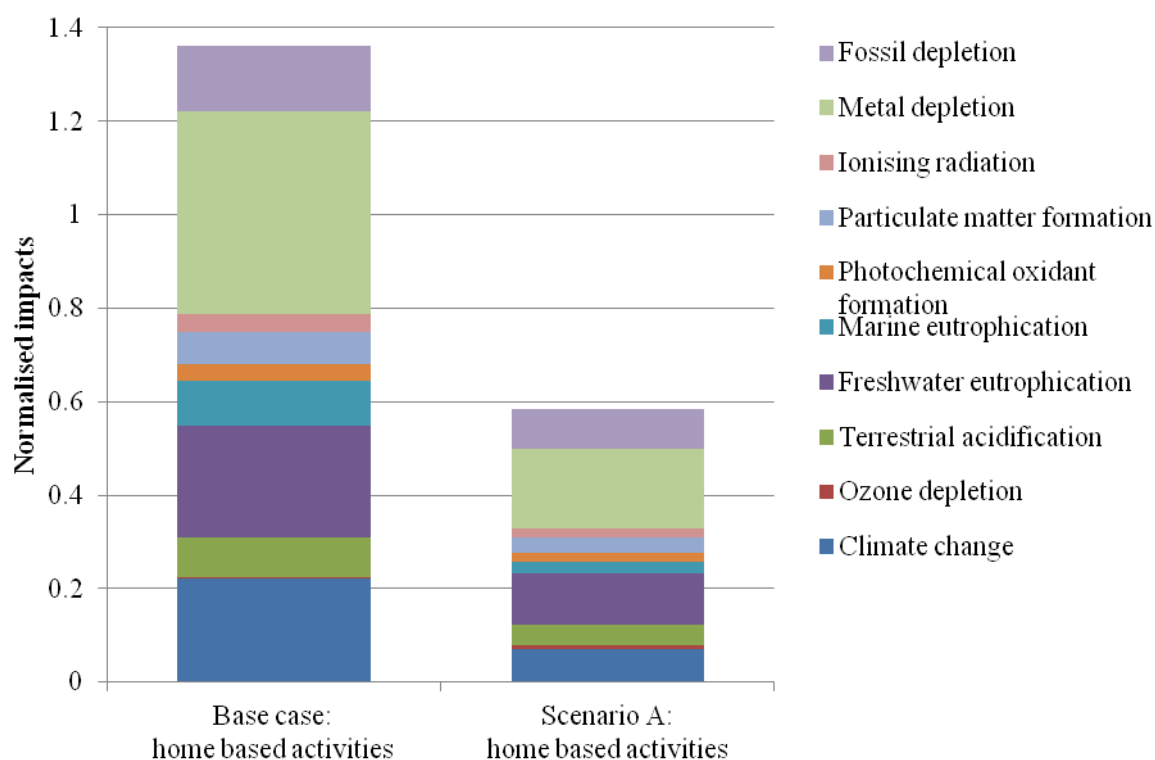


Figure 6.15: Normalised impacts comparing scenario A with the base case - ReCiPe midpoint (H)

Scenario A shows in 90% of the selected impact categories decreases were evident relative to the base parameters. The only category where there was an increase in emission was for ozone depletion. The increases in methane halons by ~110% relative to the base case can be attributed to the use of the laptop that contributed to ~77% of all emissions within this category. The three main impact categories that experienced significant decreases was marine eutrophication (~75%); climate change (~68%) and metal depletion (~61%). The decreases in impacts relative to the base case can be explained by reductions in gas heating (~25%); lighting (~36%) and computer accessories and equipment by ~53%. The reduction in gas heating can be explained from the responses of the respondents to the survey that they have heating on for half of the study period. The reduction in lighting can be attributed to the use of localised specific data as opposed to the use of modelled data and the reduction in computer accessories and equipment can be explained from the use of laptops as opposed to the generic LCD monitors, the desktop computers and accessories. The base case parameters modelled upon the course guidelines and rubric over estimated the environmental impacts of the home based activities by ~134%.

The results from the development of scenario B are represented graphically in Figure 6.16. The figure shows the significant impacts relative to the base case when laptops replace LCD monitors,

desktop computers and the additional office computer accessories for instance keyboards, when diesel is used instead of petrol to power car transport, and uncoated paper is replaced by coated paper and electric heating with gas heating from a condensing boiler.

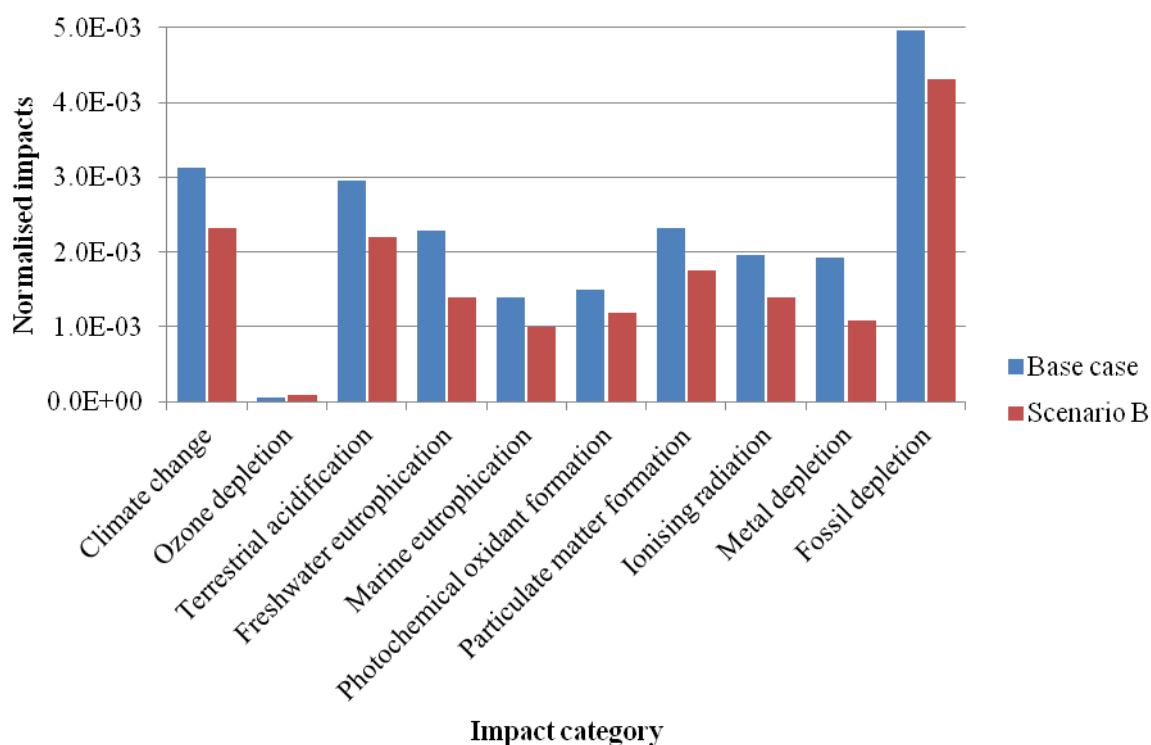


Figure 6.16: Normalised impacts comparing scenario B with the base case - ReCiPe midpoint (H)

In 90% of the impact categories there was a reduction in emissions relative to the base case (see Figure 6.16). The three main categories that experienced the largest reduction in emissions was metal depletion, ~44% decrease in iron equivalents from 1.38kg Fe eq. to 0.77kg Fe eq. Freshwater eutrophication resulted in a decrease in phosphate equivalents to water by ~39% from 0.0005kg P eq. to 0.0003kg P eq and ionising radiation a reduction of ~30% from 12.25 to 8.70kg U²³⁵.

The main contributor to metal depletion was the use of desktop computers, which contributed, in the base case to 0.68kg Fe eq. of the impact category. The use of laptops by the office employees in Scenario B reduced the amount of metal consumed by equipment to 0.28kg Fe eq. thereby reducing the overall impact on this category. Freshwater eutrophication, the main contributor was the use of uncoated paper by the office that contributed ~32% to the category. The use of coated paper in Scenario B contributed ~25% to the category thereby, explaining the decrease in emissions for this impact category from this source. The two main contributors in the base case to ionising radiation were the network based activities associated with the website (~33%) and electric space heating which contributed to ~28% of the emissions within this category. The application of gas space heating used in Scenario B assists in reducing the overall emissions and impact on the

ionising radiation category; contributing 0.03kg U²³⁵ as opposed to 3.36kg U²³⁵ from the electric space heating. Accordingly, in considering Scenario B there was an overall decrease in impacts by ~26% relative to the base case.

The results from Scenario C are illustrated in Figure 6.17, which shows the largest impacts relative to the base case. The parameters identified in Scenario A and B were utilised in C.

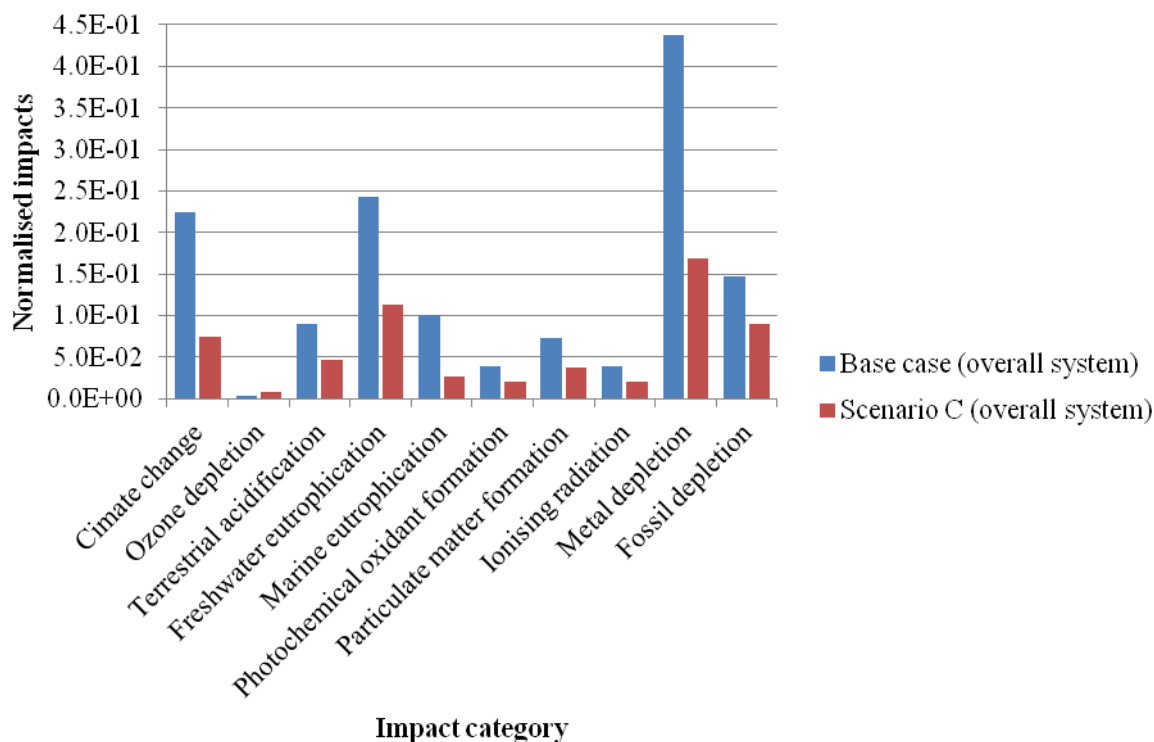


Figure 6.17: Normalised impacts comparing scenario C with the base case - ReCiPe midpoint (H)

In 90% of the impact categories, there was a reduction in emissions in scenario C relative to the base case. The three largest reductions relative to the base case were for the impact categories marine eutrophication a ~73% reduction in emissions resulted, climate change a ~67% reduction and metal depletion a ~61% reduction. The main contributors to marine eutrophication for the base case relative to scenario C were equipment, most notably LCD monitors, desktop computers and the disposal of waste to landfill. The application of scenario C relative to the base case resulted in a reduction in emissions from equipment and waste by ~79% and ~17% respectively.

The main contributors to climate change in terms of the base case was LCD monitors and desktop computers which contributed in total ~1968kg CO₂ eq. and natural gas used for space heating, contributing ~234kg CO₂ eq. These aspects contributed to ~87% of the total emissions (~2525kg CO₂ eq.) attributed to this category. Scenario C resulted in a decrease in emissions to the impact category from equipment and space heating by ~77% and ~25% respectively. The reduction in

emissions is attributed to the use of laptops and the decrease in gas consumption for space heating when students are studying.

Metal depletion was highlighted as a beneficiary from the application of scenario C. The main contributors to metal depletion in the base case were the metals used in the production and manufacture of electronic equipment, desktop computers and LCD monitors and computing accessories most notably keyboards. The equipment contributed in total 277.79kg Fe eq. and the accessories 12.6kg Fe eq. thereby contributing to ~93% of the impacts for this category from a total of all processes, ~313kg Fe eq. In scenario C less equipment was needed therefore, the consumption of metal was reduced. The use of less equipment (97kg Fe eq.) and accessories (3kg Fe eq.) resulted in a reduction in metal consumption by ~65% and ~74% respectively. Subsequently, scenario C resulted in an overall ~57% reduction in emissions relative to the overall base case system and highlighted the importance of material choice and energy in SMEs generally.

6.3.2.3. Single issue assessment

Climate change is of particular interest to SMEs because of its associations with global warming and carbon foot printing. The use of this parameter to reflect savings in terms of costs for energy and carbon makes it is a versatile and perceivably understandable category among the population. The partial analysis was undertaken on materials, processes and components that had been identified in the midpoint analyses as contributing to their respective impact categories of being $\geq 5\%$. The aspects encompassed transport, energy, equipment and consumables. In addition, regional meeting parameters were considered using online conferencing as opposed to travel by train. The analysis was undertaken using the single issue IPCC GWP 100a to quantify carbon emissions relative to the base cases for the overall system boundary and separately for the local based activities. The findings are presented in Tables 6.6 and 6.7, respectively.

Table 6.6: Single-issue assessment for the ODL company's overall service boundary

Cases	Variable case	Base case aspects	Changes made to base case aspects	Results from base case changes
<i>a</i>	Fuel parameters	Petrol	Diesel	No change
<i>b</i>	Transport parameters	Private car	Public transport	No change
<i>c</i>	Space heating parameters	Electric heating	Gas heating	No change
<i>d</i>	Consumable parameters	Paper uncoated	Paper coated	No change
<i>e</i>	Equipment parameters	Desk tops, monitors, mice and keyboards	Laptops, no keyboards or monitors	~65% decrease
<i>f</i>	Operational parameters	Desk tops (250W); monitors (72W)	Energy star desktop (65W); monitor (22W)	~3% decrease
<i>g</i>	Operational & equipment parameters	Desk tops (250W); monitors (72W)	Energy star laptop (50W); sleep mode (2W)	~69% decrease
<i>h</i>	Regional meeting parameters	Train	Online conferencing	No change

The key findings relative to the overall system were as follows:

- The changes made to fuel, transport, space heating and consumables was found to have no impact upon the overall system
- The electronic equipment used was found to influence the production of carbon emissions. The use of laptops was found to be a more preferential option than desktops and their accessories resulting in a ~65% decrease in carbon emissions
- The use of laptops and 'energy star' operational parameters resulted in a ~69% decrease in carbon emissions showing, the benefits of automatic power management features in the reduction of emissions and eco-designed office products
- Data used to model video conferencing, proved inconclusive and further research is needed to determine, the benefits for service industry SMEs generally, although an average of ~1000km was avoided train travel

The reduction in the carbon burden for the overall system has been identified. The reduction in carbon relative to the local based activities that the SME has an immediate influence upon was undertaken to identify the magnitude of the effects relative to the base case for the locally based office activities. The results from the analysis are presented in Table: 6.7.

Table 6.7: Single-issue assessment for the ODL local based activities

Cases	Variable case	Base case aspects	Changes made to the base case aspects	Results from base case changes
<i>i</i>	Fuel parameters	Petrol	Diesel	~2% decrease
<i>j</i>	Transport parameters	Private car	Public transport	~5% decrease
<i>k</i>	Heating parameters	Electric heating	Gas heating	~22% decrease
<i>l</i>	Equipment parameters	Desk tops, monitors, and keyboards	Laptops, no keyboards or monitors	~25% decrease
<i>n</i>	Operational parameters	Desk tops (250W) & monitors (72W)	Energy Star: desktops (65W) & monitors (22W)	~6% decrease
<i>m</i>	Equipment & operational parameters	Desk tops (250W) & monitors (72W)	Energy Star; laptops (50W); sleep (2W)	~30% decrease

The findings for the variable analysis relative to local based activities for the e-business were as follows:

- Alternative, fuel options as opposed to petrol should be considered to reduce carbon emissions
- Public transport should be supported and used as the preferred opposition over the use of private transport
- Space heating needs consideration and gas as opposed to an electric source would be the preferred option
- Equipment should be '*technology refreshed*' to ensure that energy efficiency can be maximised

Subsequently, for scenarios A, B and C relative to their specific base cases there was a potential to reduce overall impacts and the burden further by using energy efficient products.

6.3.2.4. Analysis and current research literature

The collected data was re-arranged into the following associated categories; campus site, travel, computing, paper/print and residential heating. The results of the analysis are presented in Figure 6.18 labelled *Distance: Online* within the comparative context of work, undertaken by Roy *et al.*, (2008) and his colleagues on the amount of carbon emissions produced by one student for differing learning systems in relation to 10 CAT points. In the paper presented by Roy *et al.*, (2008) the learning systems campus based, full and part-time are self-explanatory. The print-based and electronic systems refer to distance part-time study courses. The former course; is supplied '*mainly via printed materials*', the latter, '*mainly or partly online via the internet*'. In this instance, the contribution is in terms of part-time distance learning courses delivered only online via the internet.

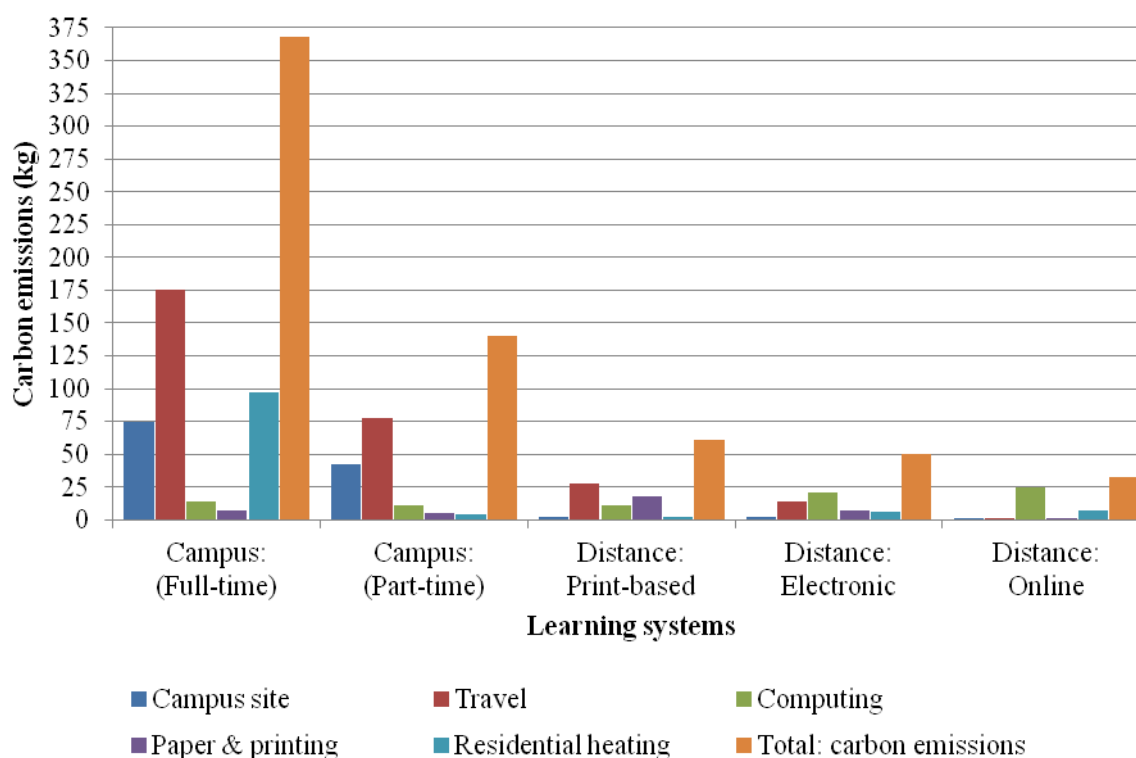


Figure 6.18: Carbon emissions produced for different learning systems that equated to 10 CAT study points (Campus and distance print based and electronic systems illustrate findings as interpreted from a paper by Roy et al. (2008) as read from Figure 1 page 122)

The key findings from this part of the analysis where the mode of delivering learning was only online included the following:

- on average the total amount of carbon emissions produced for delivering 10 CAT points using online distance learning was ~33kgCO₂;
- relative to the traditional campus based options (full and part-time) the online system resulted in reductions in the total amounts of carbon emissions produced on average by ~91% and ~76% respectively
- the online system relative to the distance learning system print based and electronic resulted in reductions in the total amount of carbon emissions produced by ~46% and ~34% respectively

Subsequently, the online distance learning produced significantly less carbon emissions than other traditional and distance based systems. The significant decreases in the amount of carbon produced by the online learning system is attributable to less travel, the limited use of paper and printing and utilisation of the campus site. The online learning system is dominated understandably by the emissions produced from activities associated with computing; and residential heating that contribute to ~75% and ~22% of the total emissions within that system.

In terms of distance learning systems, computing for the print-based contributed to 18% of the total emissions within that system and for the electronic delivery 42% of emissions resulted from computing activity. Residential heating contributed to just over a fifth of carbon emissions produced within the online system. In relation, to the distance learning systems, print-based, residential heating contributed 3% of emissions to its overall system and for the electronic, heating contributed 12%.

The dominance of residential heating within the online system in comparison to the other learning distance systems, potentially, can be explained by the contributing '*rebound*' effect. Roy *et. al* (2008) highlights this phenomena by explaining students working on their online courses may be leaving home heating on longer when they are working late in the evening. The 100% online course confirms the '*rebound*' effect by showing a ~17% increase in carbon emissions from residential heating relative to the distance electronic system, which was '*delivered mainly or partly online*'.

6.3.3. Potential for improvement

Service industry SMEs can reduce their environmental impacts by using laptops and their accessories and appropriate power management facilities. The expectation was that video online conferencing would have resulted in a decrease in carbon emissions by being offset by the regional travel. The environmental impact of the alternative option was inconclusive resulting in no change to the production of carbon emissions. In terms of the human issues however, online conferencing results in less time travelling, reduced travel costs, better management of time and reduced stress.

At an office level, on a localised basis the environmental impacts can be reduced by considering their mode of travel and choice of fuel used in private vehicles and for space heating. The reduction in the environmental burden is relevant to a small service provider. The amounts although small this needs to be seen in the context of marginal gains; future predictions and forecasts in which the cost of impacts will effectively rise.

The reduction in consumption or the substitution to a cleaner cheaper fossil fuel for instance natural gas benefits the company in terms of cost and the environment in relation to a reduction in impacts. A radical overhaul of activities related to SMEs is not possible because most offices premises are rented and the influence of the company is limited. Subsequently, although reductions in carbon emissions can be sought potentially from changing to a renewable source, the only way for a small SME to afford this form of carbon neutrality would be to re-locate to an all-purpose environmentally sustainable leasehold business park.

The findings between the distance: electronic as presented by Roy *et al.* (2008) and the distance: online as presented by the author can potentially be attributed to the former learning system being '*delivered mainly or partly online via the internet*', and the '*rebound*' effect (Herring & Robin, 2007). Roy *et al.* (2008) highlights this phenomena explaining that students on electronic courses may be leaving home heating on longer when they are working online, on course materials late in the evening.

The 100% online distance learning system when compared with a traditional campus learning systems produces significantly less carbon dioxide emissions. The providing and promoting of a 100% online HND Level 5 distance-learning course ensures that the environmental impacts for this company is minimised because of reduced travel, minimal use of the office facilities in relation to the student numbers and less paper use and printing. The dematerialisation that online learning potentially offers by the reduction of material inputs and therefore, outputs in the form of emissions would need further exploration to confirm.

6.4. Summary

This chapter undertook and completed an assessment of environmental aspects using a RLCAA based upon a magnitude approach for three service industry SME case studies. The service provided by the packing company found the three main environmental burdens were fossil depletion, terrestrial acidification and particulate matter formation, which contributed ~26%, ~16% and ~13% respectively.

The normalisation of the characterised data identified the significant impact categories within the service and the hotspots. The main hotspots within the service in which the company has direct control over and contributed 5% or greater relative to the total impacts was for the material used in the packing of the artwork, *peanuts* and equipment. The three key impacts identified for the packing *peanuts* were fossil depletion (~43%), climate change (~13%) and freshwater eutrophication (~12%) and for the computer and accessories; metal depletion (~51%); freshwater eutrophication (~25%) and terrestrial acidification (~6%). To reduce environmental impacts these areas of the service needed addressing.

The use of equipment and packing *peanuts*, were determined as a potential environmental concerns. The development of an improvement scenario to address the equipment selected for use by the service resulted in a ~ 3% reduction in environmental impacts. A starch crop-based source is considered within the packaging market to be more eco-friendly than a petroleum-based product. The development of an improvement scenario to address the packing *peanuts* and to reduce the environmental impacts resulted in a ~4% increase in the environmental burden to deliver the service.

The film company, overall the approach found the service's three largest contributions was to fossil depletion (~23%); metal depletion (~17%) and climate change (~16%). Subsequently, to shoot, produce and edit one minute of film for a documentary produces ~48kgCO_{2e}. In terms of the three stages in the filming of the documentary, the post- production stage contributed to ~71% of the environmental load. Aspects within this stage that contributed most were identified as the energy used in heating (~23%) and for electricity (~20%) and the processes used in the manufacture of the editing screens (~19%).

The improvement scenarios based upon the findings and mindful of SMEs mitigation approaches, that need to be low investment, minimal effort and ease of implementation, addressed the excessive use of film and editing equipment. This resulted in a ~7% decrease in impacts for the overall service.

The results for the ODL company show that for the overall service, the three main impact categories, the service contributed to was; metal depletion (~31%); freshwater eutrophication (~17%) and climate change (~16%). The midpoint analysis showed the home and local based systems contributed to ~99% of impacts relative to the network and regional systems. The significant impacts within the home based system was identified as metal depletion, freshwater eutrophication and climate change and the dominant contributor to these categories was the computer equipment used by the students.

The hotspots identified within the home based system modelled on the course study guidelines came from the equipment used in distance learning. The desktop computer contributed ~74% to the metal depletion category; and ~64% to the freshwater eutrophication. The LCD flat screen's main contribution was ~71% to the climate change category. The 100% online distance-learning mode of delivery within this system contributes significantly to environmental impacts because of the economies of scale.

The significant impacts identified within the local based system in which the company has more direct control included fossil depletion, freshwater eutrophication and climate change. The key components and processes that contributed significantly to fossil depletion were electric heating (~45%); passenger transport (~16%) and electricity used to operate office equipment (~10%). Freshwater eutrophication, the significant impacts resulted from paper usage (~40%); desktop computers (~20%) and passenger transport (~10%). Climate change, the three main contributors were; electric heating (~34%); office monitors (~25%) and passenger transport (~11%).

The improvement scenario developed for C (see Figure 6.17) based on the hotspots; and primary data from the students showed an overall reduction in emissions by 57% relative to the base case.

The significant reduction in the environmental impacts is attributed to the use of primary data collected from the students. The initial base case was modelled on the course rubric and the worst-case scenario in terms of equipment used by the student. This resulted in an overestimation of environmental impacts by ~134%. This brings into focus the importance of primary data and the types of equipment and materials used.

In the context of other modes of learning systems and the research literature, the online system resulted in decreases in the total amount of carbon produced by more than 50%. The findings potentially show the benefits of dematerialisation however, further work is needed to confirm and determine the contribution made by the '*rebound*' effects.

The following chapter using the parameters established in Chapter 5 and building upon the findings from the magnitude approach applies in Chapter 7, a pragmatic approach to each of the three case study companies.

Chapter 7

Results: Pragmatic Approach

This chapter presents the second part of the results relevant to *Objective III*, which assesses the environmental aspects of selected SME case studies using RCLAAs. In this chapter, the focus is upon the findings from the application of a pragmatic approach that uses guidelines and protocols as advocated by Graedel (1998) and a matrix tool. In accordance, with the parameters established in Chapter 5 and the structure in Chapter 6, this chapter reports and discusses the results from the packing company, then the film and finally, the ODL company.

7.1. Packing company

The result from the analysis using the pragmatic approach for the service provided by the packing company is detailed in this section.

7.1.1. Service rating

The assessment of the packing company using the scoring guidelines and protocols designated by Graedel, (1998), resulted in an environmentally responsible service assessment rating by life stages being produced (see Table 7.1). The service assessment relative to the functional unit evaluates aspects of the service in terms of environmental concerns or stressors.

Table 7.1: Environmentally responsible service ratings by life stages for the packing company (showing matrix element indices used to create the target plot and element values with explanations for the assignment of valued integers where 0 has the highest impact on the environment and 4 the lowest)

Life stages	Environmental concerns/stressors	Matrix element indices	Element value	Explanation/justifications
1. Facility development	Ecological impacts	(1,1)	4	No biotic impacts as the facility was already developed therefore of no concern.
	Energy use	(1,2)	4	No concern as no additional facility development needed to provide service.
	Solid residues	(1,3)	4	Additional facility development not needed, therefore of no concerns.
	Liquid residues	(1,4)	4	No additional site development needed, no concerns for liquid residues produced.
	Gas residues	(1,5)	4	No gaseous residues resulting as no additional development to facility needed, therefore of no concerns.
2. Service provision	Material choice	(2,1)	1	No environmentally influenced choices made in terms of the hardware equipment used in the service therefore, of significant concern.

Life stages	Environmental concerns/stressors	Matrix element indices	Element value	Explanation/justifications
	Energy use	(2,2)	4	Equipment powered down when not in use therefore, no concern over energy use
	Solid residues	(2,3)	4	None generated from equipment preparation.
	Liquid residues	(2,4)	4	None generated from equipment preparation therefore, of no concern.
	Gas residues	(2,5)	2	Minor concerns, as gaseous residues produced from older equipment.
3a. Performing the service	Material choice	(3a,1)	1	Scare consumables are used to make featured packing materials, for instance, the petroleum based polystyrene 'peanuts' and blocks; therefore a significant concern.
	Energy use	(3a,2)	1	Air and road activity is used in connection with the service; a significant environmental concern.
	Solid residues	(3a,3)	4	Solid packing 'waste' residues reused as packing therefore, of no concern.
	Liquid residues	(3a,4)	4	No liquid residues are produced in providing the service therefore, no concerns.
	Gas residues	(3a,5)	1	Service transport emissions generated from activity, environmentally of significant concern
3b. Facility operations	Material choice	(3b,1)	4	Fluorescent strip lighting used of no environmental concerns.
	Energy use	(3b,2)	2	UK energy mix expended on lighting, moderate concern; as a potential to minimise the impact using a green energy provider.
	Solid residues	(3b,3)	4	Some solid residues from contaminated waste packaging; of no concern because minimised as much as possible.
	Liquid residues	(3b,4)	4	No liquid residues produced by the unit.
	Gas residues	(3b,5)	3	Operations-related transport of minor concerns from collecting the artwork from the auction house.
4. Service closure	Ecological impacts	(4,1)	4	Facility can be reused therefore, limited impact on biota and of no concern.
	Energy use	(4,2)	4	Negligible energy consumption required for service closure.
	Solid residues	(4,3)	3	Equipment can be reused or recycled, along with activity consumables; although minor concern for the appropriate disposal of outdated and older models.
	Liquid residues	(4,4)	4	Negligible liquid residues will be produced in the event of service termination.

Life stages	Environmental concerns/stressors	Matrix element indices	Element value	Explanation/justifications
	Gas residues	(4,5)	4	Negligible gaseous residues will be produced in the event of service termination.

The resulting element values from the assessment was attributed to a matrix element indices to create the life stage assessment matrix, which was reflected in the target plot that highlighted graphically the hotspots and the potential for improving environmental performance within the system.

7.1.2. Life stage assessment

The evaluation in Table 7.2 shows performing the service contained the significant hotspots, which is reflected in the score 11/20. The materials used in the service, the influence of transport and the production of emissions to air contributed to the score where 60% of the environmental concerns and stressors were categorised as being significant. The main environmental concerns within the system were identified as the choice of materials and gaseous residues, which equally scored 14/20, and can be attributed to the materials, equipment and transport activity used in the service respectively. The latter activity, which can encompass CFCs, HCFCs however, within this system was, notably GHG, NO_x, CO and hydrocarbons.

Table 7.2: Matrix element indices with values used to construct the target plot for the packing company (*parenthesis showing the element indices; element values in bold type*)

Life stages (1-4)	Environmental concerns/stressors					Totals
	<i>Ecological impacts / material choice</i>	<i>Energy use</i>	<i>Solid residues</i>	<i>Liquid residues</i>	<i>Gaseous residues</i>	
1. Facility development	(1,1) 4	(1,2) 4	(1,3) 4	(1,4) 4	(1,5) 4	20/20
2. Service provision	(2,1) 1	(2,2) 4	(2,3) 4	(2,4) 4	(2,5) 2	15/20
3a. Performing the service	(3a,1) 1	(3a,2) 1	(3a,3) 4	(3a,4) 4	(3a,5) 1	11/20
3b. Facility operations	(3b,1) 4	(3b,2) 2	(3b,3) 4	(3b,4) 4	(3b,5) 3	17/20
4. Service closure	(4,1) 4	(4,2) 4	(4,3) 3	(4,4) 4	(4,5) 4	19/20
Totals	14/20	15/20	19/20	20/20	14/20	82/100

The target plot created from the resulting assessment (see Figure 7.1) shows the system graphically where the negligible environmental concerns of the service are identified as a series of points focused towards the centre. Stages 1 and 4, outside the boundary are environmentally benign. Stages 2, 3a and 3b, within the boundary show a number of environmentally significant and moderate concerns.

7.1.3. Interpretation

The main environmental concerns are from the environmental stressors that were scored, one, (significant) and two (moderate). In stage 3a of the life cycle, performing the service has three significant environmental concerns. The use of some packing materials especially the polystyrene is of concern, as petroleum based, it is reliant upon a depleting fossil fuel source. The overall improvement of this environmental concern can be mitigated by using a different composite packing material.

The loci at (3a,2) and (3a,5) assesses the services inclusion of air and road transport within the system. Similarly, as with the magnitude approach, this is operationally part of the service but the company is limited in terms of its option to improve its energy use and gaseous residues. The larger courier companies in this instance, DHL have extensive emissions management programmes for their vehicles. An option to improve the environmental performance of this life stage could be to *charge* the transport and make it the responsibility of the customer and not the company (Graedel, 2003). This approach would improve environmental stewardship in relation to the service and enable the company to focus on environmental improvements that can be developed and sustained.

In stage 2 at loci (2,1) and (2,5) the stressors were scored as of significant and moderate concern respectively. The focus of the service provision is the equipment hardware used to conduct the service. To reduce this environmental concern, procurement equipment choices need to consider the environmental options. At stage 3b, the environmental concern is the energy use by the packaging facility. In the magnitude approach, this was not highlighted as a key issue. The use of protocols and guidelines identified this as of moderate concern and a potential for improvement in environmental performance. The suggestion would be to procure energy from a green energy provider, for instance, *ecotricity*.

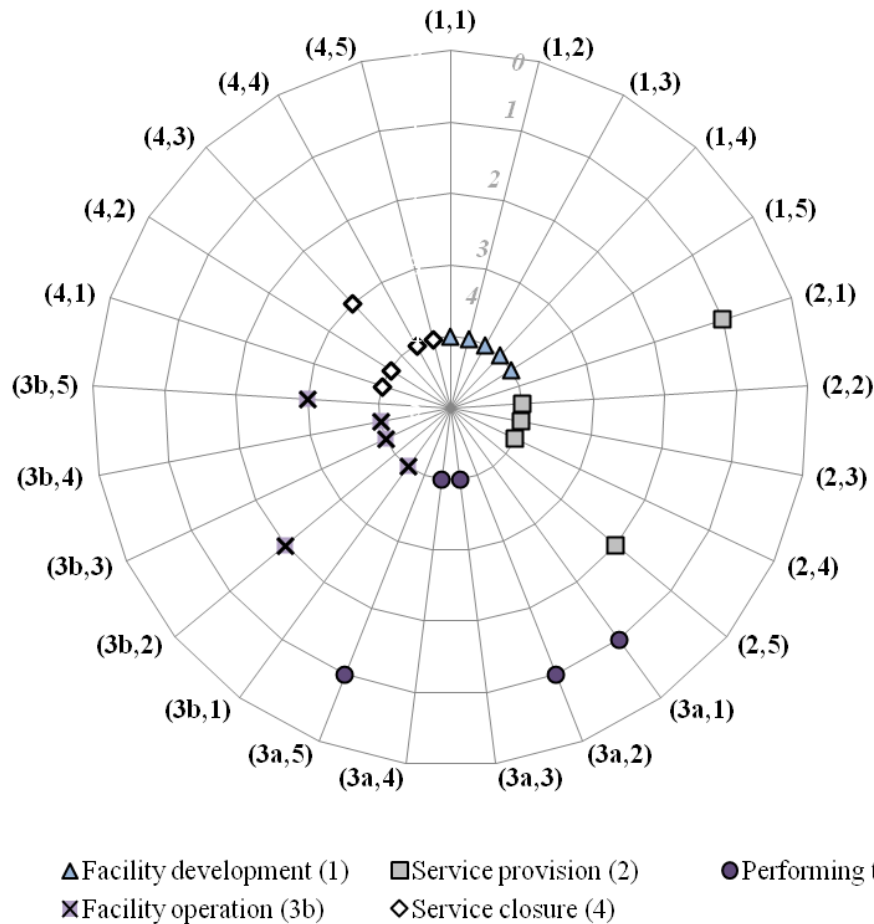


Figure 7.1: Target plot for the packing, packaging and transportation of a picture by the packing company showing the environmental concerns within the life stages (*integers in bold grey italics denote the environmental ratings*)

7.1.4. Potential for improvement

The targeting of the hotspots scoring one could improve the material choice at locus (3a,1) from a significant impact (1) to insignificant concerns (3) by following the guidance on substituting a petroleum based source for a crop-base source. In this instance, if the option to improve the environmental concern was to consider the use of starch-based packing *peanuts* which is marketed as an environmentally friendly alternative to polystyrene, the environmental concern at locus (3a,1) could be reduced from significant to insignificant concerns because this consumable is not considered a scarce or toxic material. The modifications would improve the overall stage from 11 to 13. Although, this scenario used with the magnitude approach that replaced the polystyrene with a starch derivative found this substitution was not an improvement (see Figure 6.3, p. 123).

Likewise, an alternative such as moulded pulp made from 100% recyclable paper and is biodegradable or the novel product the EcoCradle that emits eight times less CO₂ over its life cycle would equally reduce the environmental concern from one to three. The functionality and cost

implications of these potential products would need to be investigated in terms of the service that it needs to perform before any changes are undertaken

The environmental concerns in stage 2 can be mitigated by targeting equipment and undertaking appropriate environmental purchases with authorised labels. This can be improved as mentioned in the magnitude approach by replacing old computer systems when appropriate with *green* PC manufactured systems. The option with this approach, to ensure that environmental concerns are improved is to be guided by EU Ecolabel computers. Subsequently, the improvements made to this life stage would result in the concerns and stressors each scoring three. The environmental concerns would be considered marginal or insignificant because the materials of choice and gaseous residues resulting from the deployment of this equipment are designed to generate minimal toxic substances. The tackling of the environmental concerns would result in improving this stage overall from 15 to 18

In terms, of stage 3b the reduction in environmental burden could be improved by using a green energy provider. In this instance, by maximising renewable resources to provide energy, the moderate concern score of two would be improved to four, and there would be no concern because renewable resources would provide energy use for operations within the facility.

The effecting of environmental improvement is presented in Table 7.3, which reflects the new model that is operationally feasible for the company. The environmental improvement potential for stage 3a, performing the service is hampered by the lack of operational control the enterprise has over road and airfreight however, they have direct control over procurement choices. The lack of operational control the enterprise has over the mechanisms to control its energy use and gaseous residues means in stage 3a these environmental concerns and stressors remain potential areas for environmental improvement.

The use of the pragmatic approach found that the environmental burden for the service could be improved. To reduce the environmental concern in stage 2, service provision, hardware equipment for use by the service should be purchased from products that carry an EU Ecolabel. In stage 3a and where the company was in direct operational control the polystyrene packing material should be substituted with a crop-based source material, in this instance, a thermoplastic starch packing *peanuts* (Shanks & Kong, 2012). In relation, to stage 3b the reduction in environmental burden could be improved by using a green energy provider. Transportation, extensive air and road cannot be avoided in this service and as part of the system; the indirect way a SME can deal with a lack of operational control, as acknowledged in the magnitude approach, is to acknowledge the environmental burden by researching and considering credible carbon offsetting schemes.

Table 7.3: Matrix element indices with values showing the findings for feasible environmental improvements for the packing company

Life stages (1-4)	Environmental concerns/stressors					Totals
	<i>Ecological impacts / material choice</i>	<i>Energy use</i>	<i>Solid residues</i>	<i>Liquid residues</i>	<i>Gaseous residues</i>	
1. Facility development	(1,1) 4	(1,2) 4	(1,3) 4	(1,4) 4	(1,5) 4	20/20
2. Service provision	(2,1) 3	(2,2) 4	(2,3) 4	(2,4) 4	(2,5) 3	18/20
3a. Performing the service	(3a,1) 3	(3a,2) 1	(3a,3) 4	(3a,4) 4	(3a,5) 1	13/20
3b. Facility operations	(3b,1) 4	(3b,2) 2	(3b,3) 4	(3b,4) 4	(3b,5) 3	17/20
4. Service closure	(4,1) 4	(4,2) 4	(4,3) 3	(4,4) 4	(4,5) 4	19/20
Totals	18/20	15/20	19/20	20/20	15/20	87/100

In spite, of the limited environmental improvement strategies, there was however, a potential to effect a ~6% improvement in environmental performance. The adjustments made, with the addition of a greener energy provider (89/100) by ~9% and in considering the application of only equipment, laptop and accessories (85/100) by ~4% and, the application of only the crop-based packing *peanuts* (84/100) by ~2%.

7.2. Film company

The result from the assessment of aspects for the service provided by the film company is presented in the next section.

7.2.1. Service rating

An environmentally responsible service assessment rating by life stages, in accordance with the approach was produced (see Table 7.4).

Table 7.4: Environmentally responsible service ratings by life stages for the film company

Life stages	Element designation / environmental concerns	Matrix element indices	Element value	Explanation/justifications
1. Site development	Ecological impacts	(1,1)	4	Limited biotic impact as site was already developed to provide the service therefore, no new construction or renovation needed, although some cosmetic interior decoration for instance, painting of wood work and internal walls therefore of no concern.
	Energy use	(1,2)	4	No concern as no additional site or facility development needed to provide the service.
	Solid residues	(1,3)	3	Minor solid residues from the cosmetic interior work for instance, the disposal of used painting equipment and accessories.

Life stages	Element designation / environmental concerns	Matrix element indices	Element value	Explanation/justifications
	Liquid residues	(1,4)	3	Minor liquid residues from the interior work; however, remaining paint was used for community initiative projects. Residues are therefore, limited. Concerns considered marginal and insignificant.
	Gas residues	(1,5)	4	Residues from the use of paints and the effects of ' <i>outgassing</i> ' or ' <i>offgassing</i> ' which results from VOCs released by the paint, however, the amounts produced are minimal therefore, of no concern.
2. Service provision	Material choice	(2,1)	1	Post-production editing screens are of significant concerns because of the profligate use of resources. Office hardware and materials are of no concern as appropriate for the service. The specialist filming equipment is featured with aluminium, plastics, electronics and printed circuit boards and associated solders and metals. Material of choice is limited because of specialist filming equipment however, a vibrant reuse market caters for older, dated technology, negates initial concerns.
	Energy use	(2,2)	3	Office equipment used is powered down; batteries for filming accessories are charged overnight at the studio. Marginal concerns because out-of-office hours and no timers or motion sensitive switches fitted.
	Solid residues	(2,3)	4	Manufacture of equipment produces solid residues however, the equipment is produced by corporate organisations, for e.g. Panasonic whose eco ideas strategy fosters and promotes environmental protection with the reduction of CO ₂ across its manufacturing sites; therefore solid wastes are produced but minimised therefore, of no concern.
	Liquid residues	(2,4)	4	Manufacture of equipment produces liquid residues; however, the suppliers comply with stringent environmental policies and although residues are produced, they are minimised and is of no concern.
	Gas residues	(2,4)	4	No concern, because gas residues produced along their manufacturing lines are minimised in accordance with corporate sustainability strategies that are aimed at emission reduction.

Life stages	Element designation / environmental concerns	Matrix element indices	Element value	Explanation/justifications
3a. Performing the service	Material choice	(3a,1)	1	Excessive quantities filming tapes in the production stage is of significant concern.
	Energy use	(3a,2)	1	Road activity in the pre-production and production stages is used to meet new clients and carry the equipment to filming locations. The pre-production stage is of significant concern.
	Solid residues	(3a,3)	4	Solid waste residues produced off-site are disposed of appropriately therefore, of no concern.
	Liquid residues	(3a,4)	4	No liquid waste residues are produced in performing this service and therefore, of no concern.
	Gas residues	(3a,5)	1	Tailpipe emissions generated from transport is of significant concern especially, during the pre-production stage.
3b. Facility operations	Material choice	(3b,1)	3	A mixture of fluorescent and incandescent lighting present. There is a potential to improve with minor modifications, therefore, of marginal concern.
	Energy use	(3b,2)	2	Moderate concern on energy expended on equipment, and use in the studio and office.
	Solid residues	(3b,3)	3	Solid waste residues produced however, office recycling and reuse where appropriate. Marginal concerns for amount of film waste.
	Liquid residues	(3b,4)	4	No concern, as no liquid residues produced in relation to this service.
	Gas residues	(3b,5)	3	Residues from studio workers transport to the facility concern marginal.
4. Service closure	Ecological impacts	(4,1)	4	Little ecological impact as site and structures can be reused therefore, of no concern.
	Energy use	(4,2)	4	No concern, negligible energy consumption required when the service closes.
	Solid residues	(4,3)	4	No concerns equipment can be reused and recycled.
	Liquid residues	(4,4)	4	No concerns as only minor liquid residues will be produced when the service is terminated.
	Gas residues	(4,5)	4	Minor gas residues produced in the event of the service being terminated therefore, of no concern.

The assigned element value, attributed to each matrix element indices was used to create a life stage assessment matrix, which highlighted the nature of the environmental concerns and stressors within each stages of the life cycle.

7.2.2. Life stage assessment

The development of the matrix (Table 7.5) from Table 7.4 shows for the film company the life stage identified as the hotspot was performing the service, which is reflected in the low score of 11 out of 20. In relation to this stage, 60% of the stressors were ranked as being of significant environmental concern. The main environmental concerns highlighted within this stage are in the areas of material choice, energy use and gaseous residues. The materials of choice highlighted the production stage and the excessive use of film, energy use, specifically, transport and using petrol, which equally influenced the gaseous residues.

Table 7.5: Matrix element indices with values used to construct the target plot for the film company

Life stages	Environmental concerns / stressors					Totals
	<i>Ecological impacts / materials choice</i>	<i>Energy Use</i>	<i>Solid residues</i>	<i>Liquid residues</i>	<i>Gaseous residues</i>	
1. Site development	(1,1) 4	(1,2) 4	(1,3) 3	(1,4) 3	(1,5) 4	18/20
2. Service provision	(2,1) 1	(2,2) 3	(2,3) 4	(2,4) 4	(2,5) 4	16/20
3a. Performing the service	(3a,1) 1	(3a,2) 1	(3a,3) 4	(3a,4) 4	(3a,5) 1	11/20
3b. Facility operations	(3b,1) 3	(3b,2) 2	(3b,3) 3	(3b,4) 4	(3b,5) 3	15/20
4. Service closure	(4,1) 4	(4,2) 4	(4,3) 4	(4,4) 4	(4,5) 4	20/20
Totals	13/20	14/20	18/20	19/20	16/20	80/100

The main environmental stressor within the service was identified as concerning the materials used by the service, which scored 13 out of 20 of which 40% were rated as being of significant environmental concern. In terms of the overall service, ~33% of aspects from the service were highlighted as presenting significant or moderate concerns. The assessment in the matrix is presented graphically in Figure 7.2, which shows the environmental concerns and stressors that are damaging further from the centre.

7.2.3. Interpretation

In the literature based upon SME parameters and, where there is direct physical contact with the customer, using the matrix tool, only one comparable case was evident. The comparable case was a dental practice in the USA (Graedel, 2003). In this case, the life stage identified as a potential area for improvement in environmental performance, was performing the service. The literature case study can be seen as comparable to this study and the packing company. The environmental concern for the dental practice within this stage was solid residues and attributable to metal amalgam used in fillings. The importance of this stage as an area for improvement in environmental performance is it endorses the findings in this study for a typical service that conducts most of its business activities from direct physical contact with its customers. In this

research, the SMEs scored 82/100 and 80/100 respectively. In Graedel's study the practice scored 68/100, showing that current service industry SMEs and the infrastructures are potentially realising the importance of the environment.

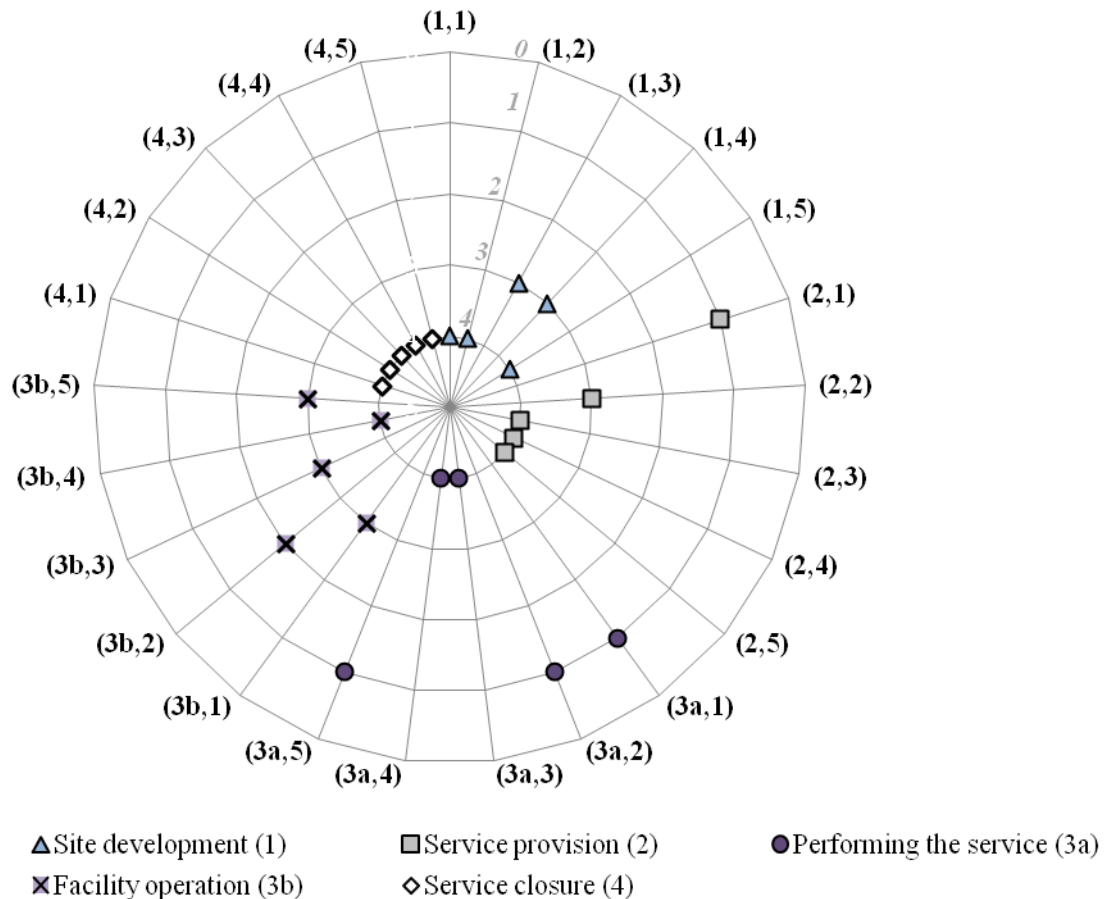


Figure 7.2: Target plot for the filming and producing of a locally based documentary showing the environmental concerns within the life stages

7.2.4. Potential for improvement

The main environmental concerns are from those areas within the service that scored one (significant) and two (moderate). At life stage 2, service provision, the editing screens identified as one of the three main contributors to the environmental burden within the post-production stage by the magnitude approach was located at locus (2,1). The use of only one screen would result in an improvement in environmental performance from (1), a significant concern to of no concern (4). Accordingly, this would improve the environmental performance of the life stage from 16 to 19 and material choice based solely on this mitigation from 13 to 16.

In relation to life stage 3a, performing the service, three environmental concerns were highlighted as cause for significant concern. The film used to shoot the documentary was identified at locus

(3a,1). The film is of concern because it is made from plastics most notably ABS and PET and is reliant upon a depleting fossil fuel, oil. To mitigate the impact a 60% reduction in film modules by using long play as opposed to short play would lessen biotic and abiotic effects owing to a reduction in the amounts of material used by the company.

Minimising the amount of film needed would reduce the environmental concern and the base environmental concern at locus (3a,1) could be reduced from a significant concern to marginal or insignificant concern because effort has been made to optimise the material and minimise the resources being used. At present, there are no available alternative materials that can be substituted which can eliminate the environmental concern. Subsequently, the environmental concern by reducing the quantity of the film used can be down-rated from a significant (1) to a marginal concern (3). This action would mitigate the environmental concern identified at (3b,3) by reducing the amount of solid residues produced by the service from a marginal (3) to no concern (4).

The type of transport used by the service was identified as of significant environmental concern within the life stage performing the service (3a) in terms of the type of energy used (3a,2) and the gaseous residues (3a,5) produced. To mitigate these concerns the enterprise in the first instance should consider in their next purchase a vehicle that is more energy efficient and uses a *greener* fuel; that is more environmentally responsive than petrol. The development of a scenario whereby the vehicle uses diesel would be credited with reducing the stressors from significant (1) to moderate (2) in relation to (3a,5) and in terms of (3a,2) to a marginal concern (3). Accordingly, in relation to energy use and gaseous residues, diesel would improve environmental performance from 14 to 16 and 16 to 17 respectively; and the life stage from 11 to 14.

A scenario developed using the alternative fuel liquefied petroleum gas (LPG) would equally improve the environmental performance of the life stage (3a) from 11 to 14. However, in this scenario the energy use from LPG is higher because of the low amount of carbon although in relation to gaseous emissions NO_x and particulates these are lower than diesel vehicles. Subsequently, energy use would improve from 14 to 15 and gaseous residues from 16 to 18, although marginal concerns still prevail because of the production of NO_x.

Mitigating the environmental concerns produced by transport is not an immediately feasible option for a service industry SME without a large investment of resources. Addressing the hotspots on a low investment, minimal preparation and effort parameters and the key environmental concerns identified within the service focuses attention upon the choice of materials within provision (life stage, 2) and performing the service (life stage, 3a). The reduction of equipment and film are credited with potentially improving the environmental performance of the stressor from 13 to 18. The life stages (3a) and (3b) result in an improvement in environmental performance from 16 to 19

and from 11 to 13 respectively. Subsequently, this would result in an estimated improvement in environmental performance for the overall service by ~8% (80 to 86) which acknowledges the reduction in solid waste residues (3b,3) to of no concern from the adoption of LP and using less film. The application of the environmental proposals to reduce the environmental concerns and stressors is represented in Table 7.6.

Table 7.6: Matrix element indices with values showing findings for the improvement in environmental performance based upon low cost, minimal preparation and effort for the film company

Life stages	Environmental concerns / stressors					Totals
	<i>Ecological impacts / materials choice</i>	<i>Energy Use</i>	<i>Solid residues</i>	<i>Liquid residues</i>	<i>Gaseous residues</i>	
1. Site development	(1,1) 4	(1,2) 4	(1,3) 3	(1,4) 3	(1,5) 4	18/20
2. Service provision	(2,1) 4	(2,2) 3	(2,3) 4	(2,4) 4	(2,5) 4	19/20
3a. Performing the service	(3a,1) 3	(3a,2) 1	(3a,3) 4	(3a,4) 4	(3a,5) 1	13/20
3b. Facility operations	(3b,1) 3	(3b,2) 2	(3b,3) 4	(3b,4) 4	(3b,5) 3	16/20
4. Service closure	(4,1) 4	(4,2) 4	(4,3) 4	(4,4) 4	(4,5) 4	20/20
Totals	18/20	14/20	19/20	19/20	16/20	86/100

7.3. Online distance learning company

The final section reports the results from the study on the ODL company, an e-business where most of its service activities are conducted electronically, and there is no direct physical contact between the provider and the customer, in this instance, the company and the student.

7.3.1. Service rating

The results from the initial assessment are detailed in the environmentally responsible service assessment rating by life stages (see Table 7.7).

Table 7.7: Environmentally responsible service ratings by life stages for the ODL company

Life stages	Environmental concerns/ stressors	Matrix element indices	Element value	Explanations/justifications
1. Site development	Ecological impacts	(1,1)	4	A purpose built business park site from 'Brownfield'. Previous use of the offices was an educational postal distance-learning provider. Refurbishment of offices was limited to interior cosmetic redecoration. Biotic impacts, limited therefore, no environmental concerns, as impacts were low.
	Energy use	(1,2)	4	The offices was used by a previous distance learning enterprise and

Life stages	Environmental concerns/stressors	Matrix element indices	Element value	Explanations/justifications
				therefore no additional energy needed for site development; telecommunications infrastructure and computer networking <i>in-situ</i> only needed to be connected.
	Solid residues	(1,3)	3	The refurbishment of the office produced minor solid residues from cosmetic interior work and office clearance therefore, only marginal environmental impact.
	Liquid residues	(1,4)	3	The cosmetic interior work produced minor liquid residues, which produced marginal impacts on the environment.
	Gas residues	(1,5)	4	No gaseous residues produced in site development & public transport links optimised enabling commuting to be undertaken.
2. Service provision	Material choice	(2,1)	1	ICT, there is no consideration given to 'green hosting' or design and optimisation of website. Main office equipment and electrical appliances purchased and are based upon a 'can it do the job' and price. Environmental responsibility is not considered in procurement decisions and causes significant environmental concern.
	Energy use	(2,2)	2	Power management for office equipment is tasked to designated personnel (office manager) who switched off all office equipment and appliances at the end of the working day. The lack of 'green' energy efficiency equipment means there is a potential for greater efficiency hence, the moderate concerns and impact.
	Solid residues	(2,3)	3	Solid residues are produced in the manufacture of appliances and equipment. The equipment and the appliances used, although not necessarily brand leaders the manufactures adhere to companies environmental and sustainability policies.
	Liquid residues	(2,4)	3	Liquid residues are produced in the manufacture of the electrical and electronic appliances. The companies produce said products for the international market in accordance with environmental regulations and laws.
	Gas residues	(2,5)	3	Gaseous residues produced in the manufacture and running of equipment that is used to provide the service. The residues are minimised in accordance with environmental regulations and laws relevant to hazardous emissions.

Life stages	Environmental concerns/stressors	Matrix element indices	Element value	Explanations/justifications
3a. Performing the service	Material choice	(3a,1)	1	PCs and their accessories used by the tutors and, students are considered of significant concern.
	Energy use	(3a,2)	2	The concern is moderate and related to the type of equipment that is used.
	Solid residues	(3a,3)	4	Paper and printing is minimised, as any submissions of assignments or working reports are undertaken electronically.
	Liquid residues	(3a,4)	4	No liquid residues are generated from performing this aspect of the service.
	Gas residues	(3a,5)	4	Transport emissions generated are not of concern because the use of public transport is encouraged and utilised when regional meetings are needed.
3b. Facility operations	Material choice	(3b,1)	1	Old wall-mounted electric heaters considered a significant concern.
	Energy use	(3b,2)	1	There is lack of user control and understanding about the facilities' heating therefore, having significant impacts.
	Solid residues	(3b,3)	3	All waste is recycled where possible, except for food waste.
	Liquid residues	(3b,4)	4	Liquid waste is produced by this service in the form of cleaning residues but the products used are environmentally friendly; therefore of no concern.
	Gas residues	(3b,5)	1	The use of petrol driven passenger cars to the office causes significant concern.
4. Service closure	Ecological impacts	(4,1)	4	Little ecological impacts if the course is discontinued.
	Energy use	(4,2)	4	Negligible energy consumption required when the service closes.
	Solid residues	(4,3)	3	Solid waste, paper assignments shredded and disposed of appropriately; therefore no concerns. Old equipment, minor concerns for disposal.
	Liquid residues	(4,4)	4	No liquid residues produced if the course is discontinued
	Gas residues	(4,5)	4	No gas residues produced upon discontinuation.

The element values that resulted from the assessment was used to create the life stage assessment matrix. This process highlighted the life stage where the main impacts or hotspots were located and the areas of environmental concerns. The discussion on the environmental concerns and stressors as determined from the assessment for the overall service boundary is presented for the ODL course in the next section.

7.3.2. Life stage assessment

The life stage assessment matrix presented in Table 7.8 and illustrated graphically in Figure 7.3, showed the environmental hotspot was located at life stage 3b, facility operations that was scored 10 out of 20. In life stage 3b, 60% of the environmental concerns were considered significant and therefore, having higher environmental impact. In relation, to life cycle stage 3b, significant concern was expressed for the material choices, energy used by the facility and gaseous residues from petrol-fuelled transport. The main environmental concern within the overall service boundary was identified as material choice and was scored 11 out of 20, in which 60% of assessed categories were considered as having significant environmental impacts. The main materials that created concerns within the service were identified as the equipment used to develop and operate the service (life stage, 2), to perform the service (stage 3a) and to operate the facility (life stage, 3b). The environmental concerns for the overall boundary are represented graphically in Figure 7.3.

Table 7.8: Matrix element indices with values used to construct the target plot for the ODL company

Life stages (1-4)	Environmental concerns/stressors					Totals
	<i>Ecological impacts/material choice</i>	<i>Energy use</i>	<i>Solid residues</i>	<i>Liquid residues</i>	<i>Gaseous residues</i>	
1. Site development	(1,1) 4	(1,2) 4	(1,3) 3	(1,4) 3	(1,5) 4	18/20
2. Service provision	(2,1) 1	(2,2) 2	(2,3) 3	(2,4) 3	(2,5) 3	12/20
3a. Performing the service	(3a,1) 1	(3a,2) 2	(3a,3) 4	(3a,4) 4	(3a,5) 4	15/20
3b. Facility operations	(3b,1) 1	(3b,2) 1	(3b,3) 3	(3b,4) 4	(3b,5) 1	10/20
4. Site and service closure	(4,1) 4	(4,2) 4	(4,3) 3	(4,4) 4	(4,5) 4	19/20
Totals	11/20	13/20	16/20	18/20	16/20	74/100

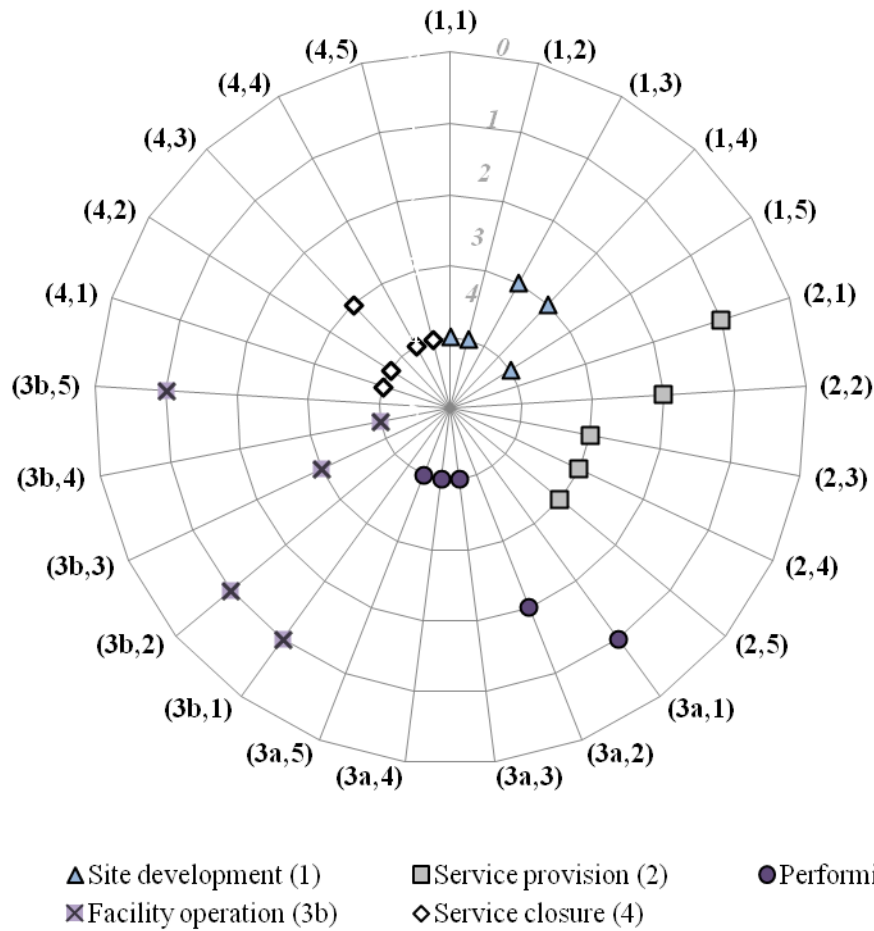


Figure 7.3: Target plot for the ODL service showing the environmental concerns within the life stages

7.3.3. Interpretation

The main environmental concerns in this instance are those impacts, which are considered significant. The environmental concerns were located in the life stages; service provision, performing the service and facility operations. The stressors were identified as material choice, located at (2,1); 3(a,1) and (3b,1); energy use at locus, (3b,2) and gaseous residues at (3b,5). Material choice in relation to the company raised environmental concerns. The company purchased office equipment that is not environmentally procured and can be seen as technology obsolete using desktops, LCD monitors and associated electronic equipment. The company can reduce the environmental impacts by considering the option of leasing equipment or purchasing environmentally appropriate equipment.

The life stage facilities operation was highlighted as an area of concern in terms of the environmental stressors related to material choice, energy use and gaseous residues. The loci (3b,1) and (3b,2) refers to the lack of environmentally influenced choices in the form of electric

panel heaters which are used to heat the offices. The gaseous residue within this stage refers to the tail pipe emissions from the petrol passenger car and is acknowledged at locus (3b,5). The environmental stressors were significant concerns and allocated a value of one. The feasibility of the company getting the property owner to install or change the heating source to natural gas is unattainable in the short-term and possibly an agenda item. The all-inclusive unit contract means that although cost savings can be made in that electricity is approximately 0.72p/kWh and gas 0.04p a unit the company would not benefit *per se*. The recourse that the company has would be to move into premises, which has the option of gas provision and is supplied independent of the business unit. In the hope that the company would be able to adopt a natural gas, provision the associated environmental stressors could be mitigated, from significant to moderate concerns.

In terms of published literature, the use of a matrix tool with parameters relevant to this case study is unknown to the researcher. The literature available considers corporate and large businesses in excess of 250 employees (Graedel, 2003). The matrix tool, identified as potential areas for improvement in environmental performance, life stage 1, site and service development. In addition, within that stage the three key environmental stressors identified were habitat/materials, solid residues and gaseous residues. The differences in the results can be attributable to the scale of site development and preparation. The larger businesses need more extensive site development and preparation as opposed to SMEs, which are sited in pre-existing properties that require negligible work to infrastructure. Accordingly, site development and preparation is minimised as reflected in the findings of this case and the other case studies.

7.3.4. Potential for improvement

The pragmatic approach identified areas, which could be improved to reduce the service's overall environmental concerns and stressors. In terms of service provision, the suggestion to replace desktops and LCD screens with appropriately leased equipment is seen as an option. The use of this option would ensure that the company; is able to manage technology obsolescence thereby keeping pace with technical advancements and cater for ease of disposal because outdated equipment can be costly to dispose.

The leased '*technology refreshed*' office equipment would assist in the reduction of energy use with the aid of power management applications, and a reduction of solid, liquid and gaseous residues by virtue of the eco-design requirements for computers and computer servers resulting from the EU regulations (2013). Subsequently, in terms of resource conservation leasing can be seen as advantageous compared to outright purchases of computer equipment (Fishbein *et al.*, 2000) thereby potentially improving environmental performance from one to four and no concern. The leasing of office equipment for small businesses however, in the UK is not culturally developed and can be an obstacle in its acceptance as a feasible business strategy. The adoption of

leased equipment coupled with the utilisation of power management facilities; resulted in an improvement in environmental performance from 12 to 16 for the life stage, service provision.

An alternative option to leasing would be the purchase of environmentally branded laptops to replace the current hardware. This would potentially improve environmental performance for the tutors. The value would be lower if appropriate end-of-life disposal and adoption could be effectively assured. The reduction in running costs can potentially be attributed to laptops conventionally drawing less power, rapidly adopting a low power state and being more likely to be switched-off and unplugged than desktops. The purchase of laptops by the tutors would reduce the concern over energy use from two to three and insignificant or marginal concerns and the overall performing the service total.

The adoption of the above recommendations by the tutors would need them to change their behaviour however; the dynamics of this is outside the scope of this study. To facilitate the adaptation of their tutors towards a greater awareness with regards their computing purchases the SME could consider the following approach based upon DEFRA's; enable, engage, exemplify and encourage strategy (DEFRA, 2005) and utilising their online presence. The company could enable their tutors by providing the necessary information about the '*green computing environment*' and the potential cost savings by their networked tutored learning space. The company could engage them via their Moodle area, exemplify by leading by example, and detail the '*green computing*' environment they have adopted. The final spoke in the DEFRA cycle is to encourage or enforce. In terms of a smaller SME, encouraging their tutors or suppliers generally to change is more beneficial as penalties and fines in this environment are counterproductive and likely to cause employment difficulties. The recommendations however, made to improve the tutors (suppliers) environmental impacts similarly in terms of the purchasing of laptops resulted in an improvement in the environmental performance from 15 to 18 for the life stage performing the service.

The tail pipe emissions from the petrol passenger car can be reduced slightly by the adoption of diesel; thereby lessening the environmental stressor. The decrease in emissions and the cheaper cost per litre of diesel makes environmental and cost saving sense. The company being able to change their car for a diesel option is feasible in the short-term and therefore, reduced to a moderate concern (2) because the fuel provision can be improved. The life stage, facilities operation equally saw an improvement in environmental performance resulting for considering gas as an alternative source of energy and the use of diesel as opposed to petrol, from 10 to 13.

The interpretation of the significant environmental concerns and application of the improvements is presented in table 7.9. The interpretation based upon the significant issues identified and the

application of recommendations and solutions resulted in an overall improvement of environmental concerns and stressors from 74 to 84, a ~14% improvement in the overall service.

Table 7.9: Matrix element indices with values showing findings for the new scenario with featured recommendations for the ODL company

Environmental concerns/stressors						
Life stages (1-4)	<i>Ecological impacts/material choice</i>	<i>Energy use</i>	<i>Solid residues</i>	<i>Liquid residues</i>	<i>Gaseous residues</i>	Totals
1. Facility development	(1,1) 4	(1,2) 4	(1,3) 3	(1,4) 3	(1,5) 4	18/20
2. Service provision	(2,1) 4	(2,2) 3	(2,3) 3	(2,4) 3	(2,5) 3	16/20
3a. Performing the service	(3a,1) 3	(3a,2) 3	(3a,3) 4	(3a,4) 4	(3a,5) 4	18/20
3b. Facility operations	(3b,1) 2	(3b,2) 2	(3b,3) 3	(3b,4) 4	(3b,5) 2	13/20
4. Service closure	(4,1) 4	(4,2) 4	(4,3) 3	(4,4) 4	(4,5) 4	19/20
Totals	17/20	16/20	16/20	18/20	17/20	84/100

7.4. Summary

This chapter undertook and completed an assessment on the environmental aspects of three-service industry SMEs using a RLCAA that was particularised by its pragmatic approach. The pragmatic approach applied to the packing company showed the three main hotspots for environmental concern was attributable to gaseous residues, material choice and energy use. The environmental stressors of significant and moderate concern were identified as resulting from the packing *peanuts*; transport activity, equipment and the energy used in the packing facility. The life stage 3a had the lowest score amongst the life stages (11/20). This stage, to perform the service, considers the actual operations; processes and materials needed to undertake the service and with 60% of its environmental concerns rated at being significant, suggested there were opportunities for improvement.

The approach highlighted the use of equipment and packing *peanuts*, as a potential environmental concern. The development of an improvement scenario to address the equipment selected for use by the service resulted in a potential to improve the environmental performance by ~4%. The development of an improvement scenario to address the packing *peanuts* and reduce the environmental concerns effected a ~2% potential improvement in environmental performance. The application of the recommendations resulted in a potential to effect a ~6% improvement in environmental performance within the overall service boundary

The concerns and stressors for the film company were located also in the life stage, performing the service (3a), which additionally rated an 11/20. Within this stage, the significant concerns (1) were identified for the materials being used, the energy used and gaseous residues. The main

contributors to these environmental concerns were from the film used to shoot the documentary and transport needed to perform the service in the pre-production stage. The improvement scenario however, based upon mitigation approaches that need to be low investment, minimal effort and ease of implementation was developed to address the excessive use of film and editing equipment. In terms of the overall service boundary the application of these recommendations, resulted in a potential to improve environmental performance by ~8% from adopting the suggestions.

The assessment of the environmental aspects for the ODL company for an electronically provided service found that the environmentally compromised life stage was facilities operations with a rating of 10 out of 20. Facilities operation highlighted the environmental concerns from operating the office during the course, which centred upon material choice, energy use and gaseous residues, which were considered of significant concerns. The main concerns centred upon material choice coupled with the energy provision from electric heating panels and gaseous residues from tail pipe emissions from petrol fuelled passenger vehicles used by employees. The applications of recommendations however, resulted in a potential ~14% improvement in environmental performance within the overall service boundary for the company. The ODL company therefore, has a greater potential to make improvements in environmental performance within its overall service boundary.

Chapter 8

Discussion

In this chapter, the discussion of the results is presented. The findings from the two RLCAAs in chapters 6 and 7 are compared and contrasted. The strengths and limitations of the research approaches as applied are critiqued and the main and wider implications of this study in relation to service industry SMEs are discussed.

8.1. Introduction

The literature review in conjunction with the pilot study suggested there was a need to evaluate the potential value of life cycle based approaches for use by service industry SMEs to measure environmental impacts. The approaches used to assess the environmental aspects of SMEs are limited and those that consider the impacts are used by a *minuscule* of businesses. The other approaches and tools are carbon emissions focused thereby providing a restricted view on impacts and ignoring the broader environmental issues.

Research was undertaken and approaches configured to achieve the aim, to determine whether rationalised life cycle assessment approaches (RLCAAs) are useful and suitable techniques to measure the environmental impacts of SMEs from service industries and, objectives as outlined in Chapter 1. Subsequently, evidence on the type of data that can be provided by owner-managers from service industry SMEs to report GHG emissions was established and contributed to a quantitative analysis used to report the amount of emissions being produced. A qualitative analysis was undertaken to establish the views and opinions of service industry employees from SMEs to measuring, managing and reporting GHG emissions, which additionally served to influence the consideration of RLCAAs.

Consequently, the study used two techniques, one a magnitude approach and the other, a pragmatic approach to assess the environmental aspects for three different service industry SMEs. Original research was conducted on data collected from the three-service industry companies whereupon the two approaches were trialled, and findings compared and contrasted.

8.2. Comparing and contrasting the findings from the RLCAAs

The magnitude approach in determining environmental relevance highlighted the three main impact categories affected by the services, were fossil depletion, metal depletion and climate change (see Table 8.1).

Table 8.1: Main impact categories identified by the magnitude approach

	Impact categories					
<i>Companies</i>	Fossil depletion	Metal depletion	Climate change	Terrestrial acidification	Particulate matter formation	Freshwater eutrophication
<i>Packing company</i>	X			X	X	
<i>Film company</i>	X	X	X			
<i>ODL company</i>		X	X			X

In terms of individual case studies, the assessment identified for the packing company three main environmental impacts (see Table 8.1). All three of these environmental impacts were attributable to freighting the picture by air as part of the service. Fossil depletion arose from the fuel needed for the aircraft, terrestrial acidification and particulate matter formation, the deposition and particulate emissions caused in the operation of the aircraft.

The film company, similar to the packing company fossil depletion was a significant impact category within the system however; the source of this impact was from equipment and energy used to heat premises. In contrast to the packing company, metal depletion and climate change were identified and arose as a consequence of the manufacture and production of equipment needed to operate and perform the service.

The magnitude approach showed aspects in the production and manufacture of IT equipment influenced the impact categories for the ODL (see Table 8.1). Similar to the film company metal depletion and climate change was a potential issue resulting from the components and processes used in the manufacture and production of equipment in connection with the services. The pragmatic approach, for both packing and film companies, performing the service was a potential area where improving environmental performance could be focused (see Table 8.2).

In addition, within this stage, the environmental stressors for both companies were highlighted as material choice, energy use and gaseous residues. The pragmatic approach highlighted the packing and film contrasted with the ODL company. The results for the ODL company identified the life stage, facilities operation as an area where improvements could be made in environmental performance, scoring 10/20 (see Chapter 7, Table 7.8: p.172) (see Table 8.2). The main environmental stressors however, were consistent with both the packing and film companies. The differences between the companies and their stages can be attributable to the way the company

provided its service. The ODL company, an e-business conducts most of its business online, electronically through the internet; with no direct physical contact with its customers, but has support personnel that need to be located within, in this instance, an office facility.

Table 8.2. Main stages were environmental improvements need to be focused as identified by the pragmatic approach

<i>Companies</i>	Life stages				
	Facility development (1)	Service provision (2)	Performing the service (3a)	Facility operations (3b)	Service closure (4)
<i>Packing company</i>			X		
<i>Film company</i>			X		
<i>ODL company</i>				X	

Mentioned previously (see Chapter 7, p.166); comparable examples within the research literature using the matrix *tool* based upon a SME parameter are sparse. Of interest, is the literature using the *tool* to assess aspects of a service where the mode of customer interaction is electronic and where there is no direct physical contact with the customer. The focus of the literature is on large and corporate businesses (Graedel, 2003) as opposed to SMEs. The findings for the ODL company differ from those in the literature (see Chapter 7, p.173). The predisposition towards larger and corporate businesses can be attributed to the belief that the environmental performance is poor in comparison to SMEs and therefore, needs to be addressed more immediately.

The two techniques, the magnitude approach using impact categories and the pragmatic approach, environmental concerns or stressors both identified equivalent aspects used in the services. The magnitude approach highlighted that the SMEs contributed to three key impact categories, most notably fossil depletion, metal depletion and climate change. The contribution to these categories equated to the service's use of transport, equipment and energy. The pragmatic approach highlighted material choice, energy use and gaseous residues, which were equated to equipment, energy use and transport.

The RLCAA frameworks were used to develop '*improvement*' scenarios to address the hotspots and reduce environmental impacts and stressors. The pragmatic approach, if the company attended to their environmental stressors and concerns in relation to energy use, materials choice and gaseous residues there was on average a potential improvement in environmental performance by ~9%. The magnitude approach, for the packing and film companies in addressing their

environmental impacts, the reductions in environmental burden was comparable to improvements in environmental performance. Accordingly, the packing and film companies resulted in a 3% and 7% reduction in environmental impacts respectively. The pragmatic approach found a 4% and 8% potential improvement in environmental performance respectively, when feasible improvement scenarios were considered.

The ODL company, exemplifying an e-business differed when ‘*improvement*’ scenario findings between the two approaches were compared. Using the magnitude approach if the ‘*improvements*’ were attended the overall burden could be reduced by ~57% however, using the pragmatic approach a potential improvement of only 14% was calculated. The differences between the two values can potentially be attributed to the limited granularity of the service ratings used to evaluate the environmental concerns and stressors.

The two approaches, both assessed aspects of the service, identifying equivalent elements used to provide the services and the hotspots that would need addressing. The improvement scenarios show overall parity between the magnitude and pragmatic approaches for the customer-facing companies, most notably packing and film; however, in relation to the ODL, results are inconclusive. Accordingly, further work would need to be undertaken to determine how effective these less time consuming rationalised approaches are at evaluating improvements for service industries where business is conducted mainly online.

8.2.1. Limitations and strengths of the RLCAAs

One of the limitation with the tools for assessing the environmental aspects and measuring impacts for SMEs is that they lack transparency, are single issue and resource intensive. To counter these failings the magnitude approach used the transparent ReCiPe methodology and the pragmatic approach with its use of the environmentally responsible service assessment with explanations ensured transparency. Both approaches were flexible that allowed for a single-issue objective to be pursued or a range of issues, thereby not losing the wider impact details.

Resource intensity, in terms of costs, time and staff can initially been seen as a short-term problem. A new project will always be initially resource intensive. Once the framework however, has been established the amount of resources necessary will not be as considerable. Both approaches possessed resource intensive elements within their frameworks and required different types of proficiencies. The pragmatic approach based upon explanations and justifications required an appraisal expertise. The magnitude approach requires a more technical expertise, but more confidence was felt in these results because of the numerical assessment, based upon a scientifically proven and accepted methodology.

The limitation on the effects of modelling without primary data was evident especially when using the magnitude approach. In the ODL case study, the initial home based activities model for the student used official course study guidelines to model service boundaries. An additional model was developed from primary data collated from students responding to an online survey on study behaviour.

The initial home based model, compared to the *actual* study behaviour model overestimated impacts by ~134%. The implication of this finding is that policy makers need to be mindful of decisions based upon hypothetical assumption modelling without adequate and corresponding primary sourced data. A magnitude approach with primary data therefore is more suited to the development of policy initiatives than a pragmatic approach, which is less effective at highlighting the distinctions.

Data used in the modelling of '*improvement*' scenarios from databases presented limitations especially product substitutions, for eco-alternative materials. The magnitude approach using the ReCiPe methodology brought into focus that it should not be necessarily assumed that eco-derivatives are more environmentally sustainable. This was demonstrated in the replacement of the packaging '*peanuts*' whose initial constituent was polystyrene a petroleum derivative with a starch-based eco-alternative. The starch-based eco-alternative proved to be equally burdensome, resulting in a ~4% increase in the environmental burden to deliver the service.

In the pragmatic approach, the subtlety of product substitutions, for eco-alternative materials is not recognised because the guidelines and protocols used to determine the improvement in environmental performance potential are not as comprehensive. The starch-based alternative is evaluated as an improvement in environmental performance and effected a ~2% potential improvement in environmental performance. Subsequently, this approach is dependent upon the prior knowledge of the life cycle assessor or in this instance, the employee tasked to undertake the assessment. SMEs need to be aware of this factor and not only question the credentials of eco-products but also consider if the alternative options are '*fit-for-purpose*' and a viable substitution.

The suitability of the substituted packing material would need to be tested to see how effectively it performs as an alternative. This would be important as the literature notes substitutes have lower resilience, are heavier than the standard polystyrene *peanuts*; costlier and create more dust. The cost of the substitute material would mean that the costs would need to be either absorbed by the company or passed onto the customer, which could be to the detriment of the business. This lack of practical awareness is not to the detriment of the pragmatic approach. The guidance protocol that is used to score element values, increases environmental awareness, as to the service's immediate activities and highlights the influence of the supply chain.

The use of Graedel's established matrix *tool* and service rating scheme in retrospect could have been improved by reversing the hierarchy ranking for environmental concerns and stressors. The use of zero to denote a severe environmental concern and four, of no concern is seemingly counterintuitive. The consideration would be to address the ranking and deploy ratings that are not contrary to conventional expectations.

The strength of the RLCAAs however, is both proved useful and suitable techniques in assessing the environmental aspects of services and highlighting the environmental impacts for service industry SMEs. The usefulness was evident in both approaches in terms of '*completeness*' in that enough information was provided in terms of the aspects and impacts, drawing attention to those areas that potentially need to be addressed, enabling decisions to be made, but not so much as to complicate or confuse the issues.

In relation to suitability, with reference to the approaches '*fitness for purpose*' the lack of granularity with the pragmatic approach appears to compromise its application. However, further work would need to be undertaken to ascertain the extent of this lack of granularity in terms of its suitability in evaluating e-businesses and product substitutions for '*improvement*' scenarios. The strength of the RLCAAs was evident, in that both the approaches accorded that activities need to be directed towards the service's transport, equipment and energy use, which are the main contributors to environmental impacts.

8.3. Limitations and strengths of the case studies

The study used three main case studies featuring companies that typified service industry SMEs. A number of practical challenges to recruiting and collecting data from SMEs and using them as case studies were highlighted. This is evident in terms of the challenges needed to keep the companies engaged as seen by only 16% completing the project.

The reasons for withdrawal can be attributed to socio-cultural or economic factors for instance, changes to the internal environment for example, a change of management and their preferences; or the external environment, for example, the recession or '*no business benefit*'. The researcher is working with SMEs and acutely beholden to externalities, which she cannot control and this impacts on the recruitment strategy. Recruitment of SMEs requires working with a range of stakeholders, extensive networking, flexibility and acute '*soft skills*' to maintain the relationships and an appreciation of social enterprise. The collection of data from SMEs requires persistence to obtain quantity values and giving them '*ownership*' of the process but as a researcher mindful of the study's objectives.

Generic theoretical limitations of using case studies in research; are that findings are biased thereby lack reliability and as no generalisation can be established, no contribution to scientific development can be made (Gerring, 2004; George & Bennett, 2005). In this instance, these criticisms are muted. To counter the criticism of bias and reliability; the data that was collected and gathered is quantitative environmental data and not based upon subjective interpretations underpinned by a philosophical perspective but underpinned by transparent system boundaries.

To counter the lack of generalisation from using single cases this is not a major disability in this study. Generalisation from other aspects of this study have been used and complemented with the use of case studies '*to gain knowledge*' (Flyvbjerg, 2011). Moreover, in the current literature the concept of generalisation is queried in actual research where it is argued that it is overrated as a main source of scientific progress and is rarely practiced (Flyvbjerg, 2011).

The strength of using cases studies for this research is it enabled contributions to be made to the established literature on LCA and SMEs. The research provided data and evidence for the comparisons, of using differing assessment approaches that had not been previously utilised, specific to service industry SMEs not studied before.

8.4. Implications on service industries for data and the supply chain

It was established the responding service industry SMEs to the online survey produced on average ~70t CO₂e per year. To understand why just over a third of owner-managers could provide the Scope 3 data further research would be needed to ascertain the differences in approaches to data availability. Likewise, as the scale of the SME was not a factor and there were inconclusive results in terms of the premises further work is needed to determine what is preventing the acquisition of data. The importance of obtaining Scope 3 data is seen in the processed data, which confirmed and showed that the largest impact was from activities included within these parameters. Scope 3 emissions, contributed to 62% of all impacts (~3,000t CO₂e), Scope 2, 4% (~180t CO₂e) and Scope 1, 34% (~1700t CO₂e).

The study established that a sizeable part of companies' impacts, ~62% was located within Scope 3 parameters. Anecdotally, it is difficult to obtain information for Scope 3 emissions. Employees and owner-managers are confident in collating data for Scope 1 and 2, electricity. However, it was established that employees and owner-managers found it difficult to capture and collect certain aspects of Scope 3 data, thereby confirming the anecdotal evidence.

The employees reported that the production and manufacture of materials and resources used by the company was the *hardest* to collate. Owner-managers reported they would have difficulty with gathering data for the transport distance of their business waste (~75%); the production and

manufacture of materials and resources used by the company (~70%) and the amount of business waste generated (~59%). Overall, the findings showed that ~57% could not provide information for the data parameters.

Measures considered to overcome these difficulties could be to place the onus on providing the initial data to the SME on their larger down and upstream providers. The waste contractors can easily put approximate distances for the transport of business waste on their websites, which could be utilised by the businesses. In terms of the production and manufacture of materials used by the business, this could be ameliorated by getting manufacturers and producers of goods to label their products. In this instance, there needs to be a push to get a uniform standard that can be used. Alternatively, it may be beneficial to provide emission values for standardised materials that can be used by the businesses. This would require the funding for development and operational costs and cross European support. The amount of waste generated can be improved within the business itself by developing a monitoring and measuring system run by a waste champion.

To capture data on the production and manufacture of materials and resources used by the SME will need the assistance of larger actors along the supply chain in the short-term to provide the necessary information. The academic literature on the influence of the supply chain and environmental behaviour is inconsistent; with some studies showing it is a driver others it was not at getting effective changes (Preuss, 2001; Studer *et. al*, 2008). However, the use of carbon mentors within the supply chain should be further investigated (Hines & Johns, 2000; Williams, 2007). The support provided by a mentor would benefit service industry SMEs by making the task of data gathering on emissions less burdensome. At present however, SMEs will continue to struggle in providing comprehensive and quality data for Scope emissions especially, Scope 3, without the support of mentors and assistance from external agencies.

8.4.1. Limitations and strengths of the online survey

The scope data was collated from submissions made by the owners-managers from service industry SMEs to an online survey. The limitation of any data collected by an online survey has the potential for bias and uncertainty caused by the method used to contact the participant and the manner of the response (Schonlau, Fricker & Elliott, 2002). These limitations were counteracted by using elements from TDM (Dillman, 2000) and TSD (Fowler, 1993) as no formal online survey process framework had been defined. Nevertheless, the limitations of this approach are acknowledged however, the strength of this approach in terms of its potential at obtaining data accuracy to knowledge questions (Schonlau, Fricker & Elliot, 2002) and higher completion rates than paper-based questionnaires (Greenlaw & Brown-Welty, 2009) afforded its suitability for this part of the study.

8.5. Implications from roundtable discussion findings for GHG emissions

The roundtable discussion presented the views and opinions of service industry employees to measuring, managing and reporting of GHG emissions. The views of the participants were analysed using focus group analytics and from their deliberations recommendations are made within the context of political, economic, social, technology, legal and environmental factorial parameters within the SME environment.

8.5.1. Political

Existing research on the role of government in connection with SMEs is contradictory. The earlier research showed that SMEs were distrustful of state support and asserted that government and their departments had neither the experience nor the skills to advise them about running their businesses (Curran, Rutherford & Smith, 2000). The SME attitude towards government support has mellowed and matured a little and current research literature shows that the role of government is valued and pivotal in assisting with the reduction of their carbon emissions (Vickers *et al.*, 2009); which was reflected by employees in the roundtable discussion.

The employees wanted the government to provide a consistent and strong lead for their businesses in the measuring and managing of GHG emissions. The government therefore, needs to provide the SMEs with a better co-ordinated service that reduces conflicting advice and competition between schemes and agencies. This approach would increase the SME's confidence in engaging with GHG reduction initiatives thereby negating their cynicism with government initiatives.

It is recommended that future governments consider establishing a '*one-stop shop*'. The central '*hub*' should provide consistent advice, information and guidance for SMEs on all their environmental needs including how to reduce their GHGs. The '*hub*' would put a stop to the challenges faced from fragmented and confused guidance information, SMEs currently received from differing agencies and re-establish information credibility.

8.5.2. Economic

There are 25 main funds in England covering grant provisions for low carbon technologies, renewables, energy efficiency, waste management and transport (Greenwise, 2013a). There are, however, disparities between the regional availability, in terms of the assistance, the support offered and the outlay of capital required by a SME (Greenwise, 2013a). The consensus among the participants was that long-term public funding should be used to assist SMEs with the measuring and managing of their GHG emissions. In terms of future developments to curtail the challenges faced by service industries from regional, financial, and supporting disparities, the following operational framework could provide benefit.

It is recommended an operational framework for providing support and funding for SMEs in the reduction of their carbon emissions could be sub-divided into three stages. A £50 entry-level was suggested by the roundtable discussion, that is undertaken by all SMEs; a mid-level which is a co-investment initiative and is flexible to the needs of the company with loans and grants offered up to £50K and an advanced-level, where a key-stone investor is needed to invest equity into the project.

The finances for funding the scheme could be given to universities and the programmes run from local universities by their business departments; for instance as demonstrated by the Future Factory project in Nottingham. This would provide an alternative '*one-stop-shop*' (see Chapter 4, p.76) that the participants in the roundtable discussion felt they needed and provide '*added-value*' to the SME, as a university proposal as opposed to other agencies and bodies would offer and provide the following:

- local business understanding
- opportunities for knowledge transfer within existing research
- potential availability of experts who can offer solutions, have advanced data analysis capabilities and can offer appropriate training to SMEs and
- experience of handling and managing government funded programmes

The likelihood of a long-term public funded package to assist SMEs in measuring and managing their GHG emissions is compromised by government uncertainty. This means at present, the SME sector is risky and vulnerable to government policy changes (Greenwise, 2013b).

The likelihood of SMEs getting the support, direction, and guidance they need, however, is very doubtful when considering the changing network of government SME funded organisations and the commitment to reduce the public deficit. National agencies, for instance WRAP and the Carbon Trust, have had their funding severely cut (Greenwise, 2013a). On a regional level, cutbacks to local authority budgets have resulted in the dismantling of the English Regional Development Agencies, which assisted in green funding initiatives (Greenwise, 2013a). This means there are fewer resources available to help SMEs in England.

8.5.3. Social

Social factors generally focus upon the forces within society, which affects the attitudes, opinions, and views of an individual. In this instance, the findings within this parameter that affected employees in their ability to manage their GHG emissions was lack of skills and expertise. The employees recognised they lacked the skills and expertise needed to measure and manage their GHG emissions.

The long-term strategy recommendation is to ensure that all business and management courses have provision for environmental training, which includes a practical environmental module within their curriculum that focuses upon the managing of emissions and life cycle thinking to improve business sustainability. This approach would counter eco-illiteracy (Tilley, 1999a, Tilley, Hooper & Walley, 2003); raise environmental awareness and enable the pursuit of environmental activity at a higher level, thereby changing the culture of SMEs.

8.5.4. Technology

SMART technology had a limited influence on their businesses and employees were unaware of the resource efficiency technologies that could be of benefit. Research into resource efficiency practices and technologies is limited. Data is sparse on how many of these measures have been adopted by SMEs, even though research claims that energy savings are attractive and small businesses will invest in new technologies if the benefits are large enough (BIS, 2010b). It appears from the research that the limitations of data has resulted in inaccurate modelling because hidden costs have not been accurately or comprehensively represented (NERA, 2006; BIS, 2010b).

Subsequently, this undermines research claims on energy savings, investments and benefits and there remains the question as to why SMEs do not adopt energy efficiency measures. One fundamental contributing factor highlighted in this study is SMEs are unaware of the resource efficiency technologies, which can explain the lack of data. To assist SMEs in the reduction of their GHG emissions resource efficiency technologies need to be accessible to businesses and credible.

It is recommended to assist in the promotion of new technologies to SMEs and counter the challenges from lack of awareness, accessibility, and credibility; partnership working needs to be promoted. Partnership working needs to be established with the service sectors, industrial bodies, and community interest companies. These bodies and suggested mode of operation would provide the necessary credibility, exposure, and record for the adoption of resource efficiency technologies. The establishment of these partnerships first, would provide the opportunity for researchers to link into these focal points. Then, with the agreement of the relevant parties gather and collate data and develop models based on accurate hidden costs profiles for SMEs.

The better promotion of new technologies would foster use by SMEs. The utilising of established interest groups to seek out working partnerships would provide the necessary exposure and credibility for new technology that could assist in the reduction of environmental impacts.

8.5.5. Legal

The employees were receptive to the notion of the mandatory reporting of GHGs to manage emissions. The evidence in the literature presented shows that market mechanisms, self-regulation, and voluntary agreements are ineffective (Rutherford *et al.* 2000; Vickers *et al.*, 2009; BIS, 2010b). Legislation is a key driver in engaging SMEs with environmental issues. Regulations in this area would encourage greater transparency accountability, are known to reduce GHG emissions. While, the expenses attributed to enforcing the regulation can be managed with the perception of a credible threat of inspection, prosecutions and publicity, industry blitzes, on-the-spot fines and notices (MacCrory, 2006).

The participants were of the opinion that they could feasibly measure and potentially report on Scope 1 and 2 emissions using CO₂e as a quantifying unit. It is recommended that the '*tools and rules*' that are currently available should be utilised. The '*tools and rules*' used to manage carbon have procedural, technical and operational concerns however, they are being used presently by organisations and these are the best available. SMEs should therefore, start collating data for Scopes 1 and 2 and use DEFRA metrics as appropriate because as one employee said '*we have to start somewhere...*' (Participant #3).

A mandatory approach should be considered a focused option in the debate on the managing of GHG emissions by SMEs. Further empirical research however, is needed to confirm whether the receptivity of the notion is generic among SMEs or a particular sector trend, a temporary response or an indication of long-term changes in attitudes towards mandatory approaches.

8.5.6. Environmental

Environmental terms used to engage SMEs and metrics to evaluate GHG emissions were discussed. The term carbon footprint was a '*HIT*' because it was familiar and perceived by participants, '*easy to understand*' (Participant #7). The lack of standardised metric to measure environmental impacts resulted in participants expressing serious concerns that CO₂e would be the sole standard of choice because it lacks wider impact details and therefore, misleading. This is echoed in the research, in studies by Weidmann & Minx, 2007; Wright, Kemp & Williams, 2011.

It is recommended however, in the interim, in terms of future engagement with SMEs, any low carbon promotional campaign should use the term carbon footprint. The fact remains that the term carbon footprint has caught the publics' imagination and has become embedded; and as Finkbeiner (2009) remarks you can, '*Love it, leave it or change it?*' and these participants appear to love it.

8.6. Limitations and strengths of the roundtable discussion

To ascertain the views, opinions, and attitudes of employees a roundtable approach was used to collect qualitative data. The generic limitations of the roundtable approach are similar to those attributed to a specialist group interview, the focus group. The main limiting factors in this instance concerned the trustworthiness, validation, authenticity, and ability to generalise the research findings from a small sample of '*information rich*' participants (Morgan, 1998a; Krueger, 1998c; Greenbaum, 2000; Krueger & Casey 2008).

To counteract the influence of these limitations on the study, to validate the findings a summary report was sent to participants for confirmation of topic interpretation, which resulted in no amendments being needed. To ensure authenticity of the results was maintained, direct citations by the participants as appropriate was used; this reduced the potential for misinterpretation and ensured their views, attitudes, values, beliefs and opinions were voiced. In terms of trustworthiness and generalisation, the findings were given credence from published literature, which echoed some of the findings as acknowledged under the factorial parameters.

8.7. Wider implications for service industry SMEs

On a national level SMEs contribute to an estimated 38.5t CO₂ of the total UK carbon emissions currently not covered by existing policies (Carbon Trust, 2005), the adoption of '*improvement*' scenarios and the overall 8% decrease in impacts could potentially result in a reduction of ~3t CO₂ to the estimated figure. However, at a local level in the understanding that a life cycle thinking approach is promoted and adequately funded and supported by central government. The implications for an average micro-business in terms of the environmental and financial bottom line would mean a potential reduction in environmental impacts and financial savings.

The average micro-business produced per year ~18t CO₂e. The adoption of a RLCAA to assess environmental aspects and measure impacts and the development of *improvement* scenarios that considered transport, service equipment and energy, coupled with a low investment, minimal effort and ease of implementation strategy would result in a ~8% decrease in environmental impacts.

Accordingly, this would result in a decrease in emissions by 1.4t CO₂e. In terms of specifics, large reductions and savings can be potentially realised by addressing transport and travel. Annually, the adoption of video-conferencing in relation to the avoided travel to meetings has been projected to make savings of ~£862 annually. In addition, with greener fuels for instance, compressed natural gas (CNG) and liquid petroleum gas (LPG) replacing diesel and travelling to one meeting, cost savings can be made and reductions in GHG emissions. In terms of using CNG a 59% saving on the cost fuel and an 81% decrease in GHG emissions can be potentially realised. In relation to

LPG, this is equally beneficial to the company and environment resulting in a 29% reduction in the cost for fuel and a 26% decrease in GHG emissions relative to diesel use.

Chapter 9

Conclusions

(Recommendations, further work and concluding statement)

This chapter presents the conclusions from the research and addresses *Objective IV*: to draw conclusions from the analysis and highlight areas for further research. Accordingly, the rationale for undertaking the research is explained; then contributions resulting from the study against the objectives as detailed in Chapter 1 are evaluated. Recommendations from the research findings are made, in addition to where future work should be addressed based upon the study presented. Finally, a concluding statement portrays the final considerations to improving the sustainability of service industry SMEs.

9.1. Rationale

In the UK 80% of employees are occupied in the service based industries (ONS, 2011a) and they are reported as contributing to producing 60% of the UK's total carbon emissions (Marshall, 1998). There is a belief however; that the move generally towards a service based economy benefits the environment in terms of lessening the burden (Shrake, Landis & Bilec, 2011). If the government though, is to fulfil its 2020, emission targets and its 2050 vision to reduce GHG emissions smaller SMEs need to play a role in reducing their environmental impacts. Accordingly, the aim of the research was to determine whether rationalised life cycle assessment approaches are useful and suitable techniques to measure the environmental impacts of SMEs from service industries.

The pilot study demonstrated a lack of a strategic approach towards sustainability generally in terms of monitoring environmental reduction activities. One of the suggestions from employees during the roundtable discussion was to use existing '*tools*'; for instance EMSs to accommodate the measuring of emissions. The use of EMSs was investigated and assessed (see Chapter 4, pp.83-86); however, its limited uptake, lack of SMEs advancing to operational stages and its current trend of decline found the suggestion invalid. Tools presented to SMEs generally to improve sustainability and reduce environmental impacts are problematic because they lack transparency, are single issue focused (Heidrich & Tiwary, 2013) and ignore the wider impact details.

Life cycle approaches and techniques are useful tools to assess the environmental aspects of a service, estimate the environmental impacts and the identify hotspots. However, they are not considered useful for SMEs because they are resource intensive in terms of time, expense and data and are regarded as being too complex, to be of any practical use (Junnala, 2006a). The criticism is pertinent in relation to a classical '*cradle to grave*' quantitative assessment however, in terms of less quantified approaches and techniques the censure is limited but not divisive. The less

quantified approaches are underutilised by service industry companies and few researchers have applied them within the context of a SME focus (Junnila, 2006a & b).

The service industry sector is growing and therefore, responsible attitudes towards the environment needs to be acknowledged and one way to do this is by addressing the environmental aspects and potential impacts of the service using LCAs. Accordingly, by utilising less resource intensive techniques, the approaches can be promoted within service industry SMEs as a means to assess their environmental aspects thereby improving their sustainability. This study therefore, applied two rationalised life cycle assessment approaches (RLCAAs) upon three-service sector SMEs, to assess environmental aspects to achieve the aim.

Data is an important component in evaluating environmental performance of a service and for *tools* used in life cycle approaches. To appraise service industry SMEs therefore, in terms of measuring, managing and reporting emissions primary data was collected from company owner-managers and employees. This holistic study produced valuable knowledge and insight into the present situation related to UK service industry SMEs and their environmental impacts.

9.2. Contributions resulting from the research

In Chapter 1 a range of objectives were defined to achieve the aim of the research; to determine whether RLCAAs are useful and suitable techniques to measure the environmental impacts of SMEs from service industries. Accordingly, an evaluation of the main contributions arising from addressing these objectives is outlined to consolidate the completed research.

Objective 1: To identify the type of data available from owner-managers of service industry SMEs that can be used to report the amount of GHG emissions being produced

Previous work using an online survey of owner-managers about data availability in the event of reporting GHG emissions is limited. The data parameters presented to the owner-managers detailing scope activities revealed that the majority had data available and accessible for Scope 1 and Scope 2, electricity parameters. However, for Scope 3 data parameters, the majority of data was unavailable, inaccessible or they were unsure of data availability. The size of neither the company nor the type of business premises was found to have a significant association with the availability and accessibility of Scope 1, 2 or 3 data.

The submission of data online enabled the establishment of GHG emission baseline values for a range of company sizes, sole, micro, small and medium, producing on average 70tCO_{2e} a year, using government-accredited parameters and highlighted the hotspots. The areas identified as hotspots were in Scope 1, business travel in vehicles owned by the company; and Scope 3, business

travel in non-company vehicles and the production and manufacture of equipment. The development of theoretical '*improvement*' scenarios using green fuel, video-conferencing and equipment replacement identified cost saving opportunities and reduced GHG emissions. In conclusion, by addressing one aspect of the service, small marginal gains can be made which has the potential upon aggregation to improve the environmental performance of the service by reducing impacts.

This study provides new evidence based data from owner-managers on energy, transport, waste and equipment and establishes benchmark emission values. In addition, the research builds upon empirical evidence by confirming the anecdotal difficulties SMEs have in collecting information and data for Scope 3 emission sources.

Objective II: To establish the views and opinions of service industry employees from SMEs to measuring, managing and reporting GHG emissions

The employees were receptive to the idea of the mandatory reporting of GHG emissions however; a number of challenges would need to be addressed in relation to the measuring and managing of GHG emissions.

In terms of the measuring of GHG emissions; the lack of standardised '*rules and tools*' in the form of a recognised standard and established metrics; the inaccessibility to Scope 3 emissions data and, the inadequate infrastructure and support along the supply chain to assist with emissions data collection; they felt compromised participating in GHG emissions activity.

The managing of GHG emissions activity they felt was equally compromised by their lack of skills and expertise; competing work priorities and the difficulties of getting culture and behaviour change within their companies. In spite of these challenges the benefits from the activity of measuring and reporting GHG emissions was identified from the employee perspective. The employees considered the process would enable targets to be set and progress to be monitored; the supply chain pressures would be addressed and cultural change within the company would be promoted and supported.

To appease the challenges presented by the employees and ensure that the benefits to the measuring and reporting GHG emissions are met; a comprehensive and consistent long-term strategy, lead by the government, working in partnership with private and public sectors, to establish a long-term framework needs to be implemented. A number of recommendations that would assist with the transition towards the measuring and reporting of emissions are included in Chapter 8.

To the researchers knowledge this is the first study to focus specifically upon employees from service industry SMEs using a roundtable discussion to consider the views and opinions towards the measuring, managing and reporting of GHG emissions. The roundtable discussion enabled the 'voices' from the 'grassroots' to be expressed. This employee perspective was important because these individuals would inevitably be involved in implementing the measuring and managing of GHG emissions to assist with reporting within their workplaces. The research provides new empirical evidence to the debate on GHG emissions from an employee perspective.

Objective III: To assess the environmental aspects on selected SME case studies using rationalised life cycle assessment approaches

The potential environmental impacts for three-service industry SMEs were established using two different RLCAAs to assess aspects. The two techniques, one a magnitude approach the other a pragmatic approach was trialled on three SMEs that included a packing, a film and an online distance learning (ODL) company.

The magnitude approach using the ReCiPe methodology and normalised at mid-point, on assessing environmental aspects, the potential environmental issues for the packing company was fossil depletion, terrestrial acidification and particulate matter formation. The impacts were attributable to the process of air freighting. The conclusion is that where service provision is transport related, the options to minimise the bulk of their impacts is limited because they lack direct operational control. Subsequently, this brings to the fore the increasing role governments both at a national and international level need to play in assisting businesses with reducing their emissions.

The magnitude approach used to assess aspects for the film company; the environmental issues were fossil depletion, metal depletion and climate change. The impact on fossil depletion arose from the input of natural gas used to heat company premises. The impacts on metal depletion and climate change resulted from the manufacture and production of equipment used to deliver the service. The main conclusion is that embodied energy, energy used in the production and manufacture of equipment needs increasing consideration in terms of putting operational carbon in context by promoting environmental product disclosures.

The online distance learning company, upon the assessment of aspects for the service, identified the environmental issues as metal depletion, freshwater eutrophication and climate change. All of these impacts arose from the production and manufacture of IT equipment. The main contributor to these impact categories was the home-based students and tutors and not the equipment used by the service provider. The main conclusion is that an acknowledgement of the philosophy of the assessor is significant. In services conducted electronically there is greater potential to shift environmental boundaries and transfer the responsibility of the burden from the service provider to

the home-based user thereby, giving a potentially skewed representation of the environmental impacts for the service. The findings highlight the importance of transparency in terms of system boundaries in the immediate terms and shows the increasing contribution that embodied energy as a factor needs to play in a carbon reduction strategy.

The pragmatic approach guided by Graedel's protocols and guidelines, and based upon improvement in environmental performance, identified the life stage, performing the service as an area for improvement for both the packing and film companies. The environmental concern within this stage was highlighted for both companies as material choice, energy use and gaseous residues. The concerns for both service enterprises were identified as attributable to equipment and transport.

The online distance learning company revealed the life stages where improvement in environmental performance was located as facilities operation. The main environmental stressors within these stages were identified as material choice, energy use, and gaseous residues. The energy use in this instance, originated from the use to energy to heat the service's premises.

Peer reviewed literature using the SME parameter in conjunction with service industries and Graedel's approach is limited as the focus is predominately on large and corporate businesses. The main conclusion from the findings, demonstrate that RLCAA frameworks, can successfully be used in a retrospective manner to assess the environmental aspects for service industry SMEs.

Objective IV: To compare and contrast the findings from the rationalised life cycle assessment approaches to determine their suitability for service industry SMEs

The similarities between the two approaches show the impacts arose from transport, equipment and energy use. The magnitude approach assessed the aspects by determining environmental relevance and finding the three main impact categories affected by the services were fossil depletion, metal depletion and climate change. The pragmatic approach assessed the aspects by indicating the potential for improving environmental performance and highlighting material choice, energy use and gaseous residues as environmental concerns or stressors. The main conclusion is that both frameworks are commensurate and effective at assessing environmental aspects and determining impacts for service industry SMEs and resources do not compromise initial findings.

The rationalised approaches were used to develop improvement scenarios to address the hotspots and reduce environmental impacts and stressors. The improvement scenarios for the packing and film company found parity between the two approaches in terms of overall improvements in environmental performance. The findings in developing improvement scenarios for the ODL company proved inconclusive.

In addition, care needs to be taken when substituting environmental alternatives to reduce impacts and stressors especially, when using the pragmatic approach. The protocol and guidelines enables the interpretation to an *eco-product* in terms of substitution to be considered as an '*improvement*'. The magnitude approach is more judicious with the results for some *eco-product* substitutions producing inconclusive findings thereby emphasising the importance of system boundaries.

The two approaches benefit the service industry SME by affording greater understanding of the operational implications that their company has on the environment. The knowledge empowers the company by producing material results that can be used practically to improve environmental performance. Both approaches are suited to service industry SMEs however; the limited granularity from the pragmatic approach compromises its application. Accordingly, the magnitude approach with primary data is additionally suited to the development of policy initiatives than a pragmatic approach, which is less effective at highlighting distinctions.

The main conclusion is that both RLCAAs would prove useful at raising environmental awareness, assessing environmental aspects and highlighting environmental impacts, by producing similar results, less time consuming approaches can be used effectively by SMEs. The research contributes to knowledge by providing novel evidence based material for two RLCAAs, in which three different case studies were produced within this comparative index.

9.3. Recommendations

A number of recommendations can be deduced based upon the research findings. The recommendations are specified below and might be offered for the attention of government policy makers, service industry SMEs and researchers.

- Create a central information '*hub*' for SMEs run and backed by the government where data sets for SMEs are created and maintained, where quality is guaranteed for energy, transport, waste and materials
- Provide funding and promote ISO activities for research into LCA rationalised techniques to obtain agreed simplification procedures; this will provide the necessary *nudge* towards the standardisation of measurements, guidance and approaches
- Establish mechanisms to support SMEs in starting and conducting LCAs in the form of policy or business association initiatives
- Improve the competencies, information base and knowledge of employees by putting in place economic instruments for environmental training, on LCA, and the monitoring, measuring and reporting of emissions

- Establish mechanisms to reduce information barriers and encourage collaboration, communication and cooperation between stakeholders, for instance the exchange of upstream and downstream environmental information along the supply chain
- Establish minimum performance requirements on all promotional capital goods and equipment used by businesses and deter the use of underperforming equipment
- Promote eco-labels procedures to be awarded to equipment and capital goods that demonstrate 50% impact reductions over the average product
- Collect data, SMEs should try to become conversant in assessing their environmental aspects by gathering data in relation to Scope 1 and 2 emissions and follow the DEFRA reporting guidelines as appropriate in the first instance (DEFRA, 2009, DEFRA, 2013a).

9.4. Further Research

Several research opportunities were found through the research that can be used to define future work and build upon the present research. The research opportunities were identified as follows:

Regional assessment of service industry SMEs on the monitoring, managing and reporting of GHG emissions activities: A part of the study because of funding constraints was concentrated in Southern England. Further research on regional variations within the UK is required to determine if the findings are regionally specific.

Longitudinal studies on the implementation of the RLCAAs and ‘improvement’ scenarios within service industry SMEs: There is a need for more longitudinal RLCAA studies to be undertaken to determine their applicability to SMEs generally and the commercial and market benefits of undertaking and adopting these assessment to improve sustainability.

Further RLCAA studies on different SME sectors: Further studies on the role RLCAA play in the other sectors and relative to SIC, would allow assessment comparisons to be made about their applicability and relevance within the small business community.

Technical assessment of adopting full product / service transparency for service industry SMEs: The LCA approaches uses a functional unit as a quantifier however, this is can be problematic when dealing with services. Therefore, there may be an option to consider the role of declared units as an alternative to the functional unit and undertake a number of technical assessments to compare and determine its applicability.

Gender assessment of SME owner-managers to monitoring, managing and reporting of GHG emissions: The literature acknowledges that females are more environmentally conscious than

males. To consider female owner-managers in terms of the monitoring, managing and reporting of GHG emissions, focus groups to saturation point would need to be conducted. This would allow for a comparison between the genders and the development of appropriate targeted approaches if necessary.

Further LCA studies on SMEs that conduct most if their business activities online through the internet: There is a suggestion that substituting tangible services with virtual domain equivalents can assist with reducing impacts (Chowdhury, 2011). The research literature is sparse as to what extent portable technology and the internet can be used to assist with reducing the environmental impacts of SMEs. Further research is therefore, required to ascertain the effect of virtual domain equivalents within a SME context.

9.5. Concluding statement

This study began with the recognition and importance of SMEs within the economy; especially the service sector in the Western economies and the opportunity to offer life cycle thinking into smaller companies by the use of rationalised life cycle assessment approaches (RLCAAs). The key contribution of this study; is it provides evidence-based material, producing three case studies, demonstrating from the similarity of results that less time consuming life cycle techniques are suitable for service industry SMEs. Overall, the study demonstrated that RLCAAs can be used effectively by SMEs to determine and address improvement potentials and environmental priorities; provide a better understanding of organisational processes and detail a number of recommendations for interested stakeholders.

In conclusion, the use of RLCAAs among service industry SMEs should be encouraged as a means of raising awareness and gauging environmental impacts. The intention of this thesis therefore, was to promote the use of RLCAAs among service industry SMEs. By using available and accessible information, the applications show how both can be utilised effectively as useful and suitable techniques to assist and improve the sustainability of SMEs from service industries.

References

- AA (Automobile Association), 2011a. *Annual averages fuel price report* [Online]. Available from: <http://www.theaa.com/newsroom/news-2012/december-fuel-price-report.html> [Accessed: 14th February 2012].
- AA (Automobile Association), 2011b. *Fuel price reports January 2011 to December 2011* [Online]. Available from: http://www.theaa.com/motoring_advice/fuel/ [Accessed: 14th February 2012].
- Ahern, G. M., 2015. Imagining what underlies corporate sustainability. *Journal of management development*, 34(4), pp.494-504.
- Alcántara, V. & Padilla, E., 2009. Input–output subsystems and pollution: an application to the service sector and CO₂ emissions in Spain. *Ecological economics*, 68, pp.905– 914.
- Amini, M. & Bienstock, C. C., 2014. Corporate sustainability: an integrative definition and framework to evaluate corporate practice and guide academic research, *Journal of cleaner production*, 76, pp.12-19.
- Aragón-Correa, J. A., Hurtado-Torres, N., Sharma, S. & Garcia-Morales, V. J., 2008. Environmental strategy and performance in small firms: a resource-based perspective. *Journal of environmental management*, 86(1), pp.88-103.
- Avexia, 2012. *Video conferencing the costs* [Online]. Available from: http://www.avexia.co.uk/website/videoconferencing_costs.aspx [Accessed: 21st October 2012].
- Badel, A. & Martineli, C.J., 2011. Changes to the picture of the UK economy -- impact of the new SIC 2007 industry classification. *Economic & labour market review*, 5(3), pp.41-61.
- Bailey, A.J., 2000. Industrialization and economic development in advanced placement human geography. *Journal of geography*, 99(3-4), pp.142-152.
- Bandura, A., 2001. Social cognitive theory of mass communication. *Media psychology*, 3(3), pp. 265-299.
- Banerjee, S. B., Iyer, E. S. & Kashyap, R. K., 2003. Corporate environmentalism: antecedents and influence of industry type. *Journal of marketing*, 67(2), pp.106-122.
- Baylis, R., Connell L. & Flynn, A., 1998. Company size, environmental regulation and ecological modernisation: further analysis at the level of the firm. *Business strategy and the environment*, 7, pp.285-296.
- Beckerman, W., 1996. *Small is stupid: blowing the whistle on the Greens*. London: Gerald Duckworth & Co Ltd. ISBN 071562640X.
- Behn, R.D., 2003. Why measure performance? Different purposes require different measures. *Public administration review*, 63(5), pp.586–606.

Bernard, M., Liao, C. H. & Mills, M., 2001. *The effects of font type and size on the legibility and reading time of online text by older adults. Interactive posters* [Online]. Available from: http://delivery.acm.org/10.1145/640000/634173/p175-bernard.pdf?ip=138.38.72.153&id=634173&acc=ACTIVE%20SERVICE&key=BF07A2EE685417C5%2E85B475708465C551%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&CFID=706768927&CFTOKEN=94784108&__acm__=1440505560_61c75a83f8a76c6909e2ca18cf95e886 [Accessed on 25 August 2015].

Bernard, M., Lida, B., Riley, S., Hackler, T. & Janzen, K., 2002. A comparison of popular online fonts: Which size and type is best. *Usability news*, 4(1) [Online]. Available from: <http://usabilitynews.org/a-comparison-of-popular-online-fonts-which-size-and-type-is-best/> [Accessed 25th August 2015].

Berners-Lee, M., Howard, D.C., Moss, J., Kaivanto, K. & Scott, W.A., 2011. Greenhouse gas footprinting for small businesses-the use of input-output data. *Science of the total environment*, 409, pp.883-891.

Berry, S. & Ladkin, A., 1997. Sustainable tourism: a regional perspective. *Tourism management*, 18(7), pp.433-440.

BFI (British Film Institute), 2012. *BFI Film forever statistical year book 2012* [Online]. London: BFI. Available from: <http://www.bfi.org.uk/sites/bfi.org.uk/files/downloads/bfi-statistical-yearbook-2012.pdf>.

BFI (British Film Institute), 2013. *BFI Film forever statistical year book 2013* [Online]. London: BFI. Available from <http://www.bfi.org.uk/statisticalyearbook2013/>.

Bianchi, R. & Noci, G., 1998. Greening SMEs' competitiveness. *Small business economics*, 11 (3), pp.269-218.

Birdsall, S., 2014. Measuring student teachers' understandings and self-awareness of sustainability. *Environmental Education Research*, 20(6), pp.814-835.

Bititci, U., Garengo, P., Dörfler, V. & Nudurupati, S., 2012. Performance measurement: challenges for tomorrow. *International journal of management reviews*, 14(3), pp.305-327.

BIS (Department for Business Innovation & Skills), 2010a. *Statistical press release for 'small and medium-sized enterprise' (SME) statistics for the UK and regions 2009* [Online]. Available from: <http://stats.bis.gov.uk/ed/sme> [Accessed 1st November 2010].

BIS (Department for Business, Innovation & Skills), 2010b. *Green light? a review of regulatory to small businesses' resource and energy efficiency* [Online]. London: BRE. Available from: <http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file54466.pdf> [Accessed 25th August 2015].

BIS (Department for Business Innovation & Skills), 2013. *Business population estimates for the UK and regions 2013* [Online]. Available from: <https://www.gov.uk/government/statistics/business-population-estimates-2013> [Accessed 15th December 2013].

- BIS (Department for Business, Innovation & Skills), 2014. *Business population estimates for the UK and regions 2014* [Online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/377934/bpe_2014_statistical_release.pdf [Accessed 25th August 2015].
- Blackburn, R. & Stokes, D., 2000. Breaking down the barriers: using focus groups to research small and medium-size enterprises. *International small business journal*, 19(1), pp.44-67.
- Borga, F., Citterio, A., Noci, G. & Pizzurno, E., 2009. Sustainability report in small enterprises: case studies in Italian furniture companies. *Business strategy and the environment*, 18(3), pp.162-176.
- Bořkan, B., 2010. The mode effect in mixed-mode surveys mail and web surveys. *Social science computer review*, 28, pp.371-380.
- Boustead, I. & Hancock, G.F., 1979. *Handbook of industrial energy analysis*. Chichester: John Wiley.
- Boustead, I., 1996. LCA-how it came about. *The international journal of life cycle assessment*, 1(3), pp.147-150.
- Bows, A. & Anderson, K. L., 2007. Policy clash: can projected aviation growth be reconciled with the UK government's 60% carbon-reduction target. *Transport policy*, 14(2), pp.103-110.
- Bowyer, C., Monkhouse, C., Skinner, I. & Willis, R., 2005. *Business action on climate change: where next after emissions trading?*. London: Green Alliance
- Bradford, J. & Fraser, E.D.G., 2008. Local authorities, climate change and small and medium enterprises: Identifying effective policy instruments to reduce energy use and carbon emissions. *Corporate social responsibility and environmental management*, 15(3), pp.156-172.
- Brammer, S., Hoejmoose, S. & Marchant, K., 2012. Environmental management in SMEs in the UK: practices, pressures and perceived benefits. *Business strategy and the environment*, 21(7), pp.423-434.
- Braunsberger, K., Wybenga, H. & Gates, R., 2007. A comparison of reliability between telephone and web-based surveys. *Journal of business research*, 60(7), pp.758-764.
- Brio, J.A. & Junquera, B., 2002. A review of the literature on environmental innovation management in SMEs: implications for public policies. *Technovation*, 23(12), pp.939-948.
- Brock, W. A. & Taylor, M.S., 2005. Economic growth and the environment: a review of theory and empirics. In: Aghion, P., Durlauf, S., eds., *Handbook of economic growth, Vol 1*, pp.1749-1821. Netherlands: Elsevier.
- Broderick, J., 2009. Voluntary carbon offsetting for air travel. In: *Climate change and aviation: issues, challenges and solutions* [Online]. Available from: http://www.gci.org.uk/Documents/Aviation-and-Climate-Change_.pdf [Accessed on 25th August 2015].

Brooksbank, R., 1991. Defining the small business: a new classification of company size. *Entrepreneurship & regional development: an international journal*, 3(1), pp.17-31.

Brundtland, G., Mansour K, Agnelli, S., *et al.* 1987. *Our Common Future* ('Brundtland report') [Online]. Available from: Gru Brundtland, Mansour Khalid, Susanna Agnelli, Sali Al-Athel, Bernard Chidzero, Lamina Fadika, Volker Hauff, Istvan Lang, Ma Shijun, Margarita Morino de Botero, Magendra Singh, Saburo Okita, And Others [Accessed 12th April, 2016].

Bryman, A., 2012. *Social research methods*. Oxford: Oxford University Press.

BSR (Business for Social Responsibility), 2001. *Suppliers' perspectives on greening the supply chain* [Online]. San Francisco: Business for Social Responsibility Education Fund. Available from: http://www.bsr.org/BSRResources/Environment/ResourcesDoes/Greening_SupplyChain.pdf [Accessed on 18th May 2012].

Burke, S. & Gaughran, W.F., 2007. Developing a framework for sustainability management in engineering SMEs. *Robotics and computer-integrated manufacturing*, 23, pp.696–703.

Cagliano, R., Blackmon, K. & Voss, C., 2001. Small firm under microscope: international differences in production/operations management practices and performance. *Integrated manufacturing systems*, 12, pp.469–482.

Carbon Trust, 2005. *The UK climate change programme: potential evolution for businesses and the public sector* [Online]. London: Carbon Trust. Available from: <https://www.carbontrust.com/resources/reports/advice/uk-climate-change-programme-potential-evolution> [Accessed 25th August 2015].

Casey, P. & Scott, K., 2006. Environmental concern and behaviour in an Australian sample within an ecocentric – anthropocentric framework. *Australian journal of psychology*, 58(2.), pp.57-67.

Cassells, S. & Lewis, K., 2011. SMEs and environmental responsibility: do actions reflect attitudes. *Corporate social responsibility and environmental management*, 18 (3), pp.186-199.

Chowdhury, G., 2012. How digital information services can reduce greenhouse gas emissions. *Online information review*, 36(4), pp.489-506.

Church, A. H., 1993. Estimating the effect of incentives on mail survey response rates: a meta-analysis. *Public opinion quarterly*, 57(1), pp.62-79.

Clark, G., 2000. Developing better systems for communications: environmental best practice in small businesses. In: *Small and medium-sized enterprises and the environment: business imperatives*, Hillary, R., ed. Sheffield: Greenleaf Publishing Ltd.

Climate Change Act, 2008. [Online]. Available from: <http://www.legislation.gov.uk/ukpga/2008/27/contents> [Accessed 21st August 2013].

CNG Europe, 2014. *CNG Europe* [Online]. Available from: http://cngeurope.com/?page_id=24 [Accessed: 6th September 2014].

Cohen, E., 2013. *Sustainability reporting for SMEs competitive advantage through transparency*. UK: Do Sustainability. ISBN 978-1-909293-36-6.

- Collins, E., Roper, J. & Lawrence, S., 2010. Sustainability practices: trends in New Zealand businesses. *Business strategy and the environment*, 19(8), pp.479-494.
- Connell, N., 2008. *Social and environmental responsibility and the small business owner* [Online]. London: Federation of Small Businesses (FSB). Available from <http://www.fsb.org.uk/policy/assets/CSR%20Dec%202008.pdf> [Accessed 14th November 2011]
- Cooper, J.S. & Fava, J.A., 2006. Life cycle assessment practitioner survey. *Journal of industrial ecology*, 10(4), pp.12-14.
- Couper, M. P., Traugott, M. W. & Lamias, M. J., 2001. Web survey design and administration. *Public opinion quarterly*, 65(2), pp.230-253.
- Couper, M.P., 2008. *Designing effective web surveys*. New York: Cambridge University Press. ISBN: 9780521717946.
- Couper, M. P., 2000. Web Surveys: a review of issues and approaches. *Public opinion quarterly*, 64 (4), pp.464-494.
- CRiBE (Centre for Research in the Built Environment), 2009. *Greening the commercial property sector: a guide for developing and implementing best practice through the UK leasing process* [Online]. UK: The Welsh School of Architecture. Available from: <http://orca.cf.ac.uk/46207/1/good%20practise%20guide%20July%202009-final.pdf> [Accessed 25th August 2015].
- Crocker, R. 2012. SME perceptions of low carbon options: drivers, barriers and business sector differences. *Earth and the environment*, 7, pp.232-259.
- Curran, J., Rutherford, R. & Smith, S. L., 2000. Is there a local business community? explaining the non-participation of small business in local economic development. *Local economy*, 15(2), pp.128-143.
- Curran, M.A., 1996. *Environmental life cycle assessment*. New York: McGraw-Hill.
- Curran, M.A., 2006. *Life cycle assessment: principles and practice* [Online]. Scientific Applications International Corporation (SAIC). USA: EPA Office of Research and Development. Available from: http://www.epa.gov/nrmrl/std/lca/pdfs/chapter1_frontmatter_lca101.pdf [Accessed 27th August 2015].
- Darnall, N., Henriques, I. & Sadorsky, P., 2008. Do environmental management systems improve business performance in an international setting? *Journal of international management*, 14(4), pp.364-376.
- Davidson, B., 2007. *Do hairdressers really matter? Research into the carbon emissions from SMEs to assess whether they are a significant contributor to the overall GHG emissions from businesses and what ability they have to reduce their emissions*. Dissertation (MSc) University of East Anglia, Norwich.
- DECC (Department of Energy and Climate Change), 2011. *The carbon plan: delivering our low carbon future*. London: HMSO.

DEFRA (Department for Environment, Food and Rural Affairs), 2005. *Securing the future-the UK government sustainable development strategy* [Online]. London: DEFRA. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69412/pb10589-securing-the-future-050307.pdf [Accessed 25th August 2015].

DEFRA (Department for Environment, Food and Rural Affairs), 2009. *Guidance on how to measure and report your greenhouse gas emissions* [Online]. London: DEFRA. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69282/pb13309-ghg-guidance-0909011.pdf [Accessed 25th August 2015].

DEFRA (Department for Environment, Food and Rural Affairs), 2013a. *Environmental reporting guidelines: including mandatory greenhouse gas emissions reporting guidance* [Online]. London: DEFRA. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/206392/pb13944-env-reporting-guidance.pdf [Accessed 25th August 2015].

DEFRA (Department for Environment, Food and Rural Affairs), 2013b. *UK conversion factors for company reporting* [Online]. London: DEFRA. Available from: <http://www.ukconversionfactorscarbonsmart.co.uk/> [Accessed 25th August 2015].

DEFRA (Department for Environment, Food and Rural Affairs), 2013c. *Waste and recycling*. [Online]. London: DEFRA. Available from: <https://www.gov.uk/government/policies/reducing-and-managing-waste%20> [Accessed: 15th April 2013].

DEFRA (Department for Environment, Food and Rural Affairs), 2015. *UK Statistics on Waste – 2010 to 2012* [Online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/416471/UK_Statistical_release_UPDATEv6_19_03_2015.pdf [Accessed: 2nd August: 2015].

Delmas, M. & Montiel, I., 2009. Greening the supply chain: when is customer pressure effective? *Journal of economics & management strategy*, 18, pp.170-201.

Denscombe, M., 2006. Web-based questionnaires and the mode effect: An evaluation based on completion rates and data contents of near-identical questionnaires delivered in different modes. *Social science computer review*, 24, pp.246-254.

Denscombe, M., 2007. *The good guide for small-scale social research projects*. England: Open University Press.

Denscombe, M., 2008. The length of responses to open-ended questions: A comparison of online and paper questionnaires in terms of a mode effect. *Social science computer review*, 26, pp.359-368.

Denscombe, M., 2009. Item non-response rates: a comparison of online and paper questionnaires. *International journal of social research methodology*, 12, pp.281-291.

DfT (Department for Transport), 2012. *Vehicle licensing statistics: 2011* [Online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/9038/vls-2011.pdf [Accessed: 18th May 2012].

- Deutskens, E., Ruyter, K. D., Wetzels, M. & Oosterveld, P., 2004. Response rate and response quality of internet-based surveys: an experimental study. *Marketing letters*, 15(1), pp. 21-36.
- Diamantopoulos, A., Schlegelmilch, B. B. & Webb, L., 1991. Factors affecting industrial mail response rates. *Industrial marketing management*, 20(4), pp.327-339.
- Dillman, D. A., West, K. K. & Clark, J. R., 1994. Influence of an invitation to answer by telephone on response to census questionnaires. *Public opinion quarterly*, 58(4), pp.557-568.
- Dillman, D.A., Tortora, R.D., Conradt, J. & Bowerk, D., 1998. Influence of plain vs. fancy design on response rates for web surveys. Unpublished paper presented at the Annual Meeting of American Statistical Association, Dallas, Tex. In: Schonlau, M., Ronald Jr, D. & Elliott, M. N., 2002. *Conducting research surveys via e-mail and the web*. USA: Rand Corporation.
- Dillman, D. A., 2000. *Mail and internet surveys: the tailored design method*. New York: John Wiley & Sons.
- Dillman, D. A. & Smyth, J. D., 2007. Design effects in the transition to web-based surveys. *American journal of preventive medicine*, 32(5S), pp.90–96.
- Dillman D. A., Smyth, J. D. & Christian, L. M., 2009. *Internet, mail and mixed-mode surveys: the tailored design method*. USA: John Wiley & Sons.
- Directive 2004/18/EC. *European parliament and of the council of 31st March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts [2004] OJ L134/114* [Online]. Available from: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:134:0114:0240:en:PDF> [Accessed 19th August 2015].
- Drake, F., Purvis, M. & Hunt, J., 2004. Meeting the environmental challenge: a case of win-win or lose-win? a study of the UK baking and refrigeration industries. *Business strategy and the environment*, 13, pp.172-185.
- DUKES (Digest of UK Energy Statistics), 2009. *Digest of United Kingdom energy statistics 2009*. London: DECC.
- Dunn, S., 2002. Down to business on climate change. *Greener management international*, 39, pp.27-41.
- EA (Environment Agency), 2002. *Strategic waste management assessment 2002/2003: density conversion factors* [Online]. Available from: http://www.doeni.gov.uk/niea/waste_density_conversion_factors.pdf. [Accessed 1st December 2013].
- EA (Environment Agency), 2003. *NetRegs SM-Environment 2003* [Online]. Available from: http://www.netregs.org.uk/pdf/sme_2003_uk_1409449.pdf [Accessed 19th March 2010].
- EA (Environment Agency), 2012. *Water for businesses* [Online]. Available from: <http://www.environment-agency.gov.uk/business/topics/water/34866.aspx> [Accessed 18th May 2013].

EC (European Commissions), 2003a. *The definition of micro, small and medium-sized enterprises*. Source: *Commission Recommendation 2003/361/EC of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises Official Journal L 124, p. 36-41, of 20 May 2003* [Online]. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2003.124.01.0036.01.ENG [Accessed January 3rd 2009].

EC (European Commission), 2003b. *What is a SME?* [Online]. Available from: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm [Accessed 28th August 2015].

EC (European Commission), 2003c. *Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels and other renewable fuels for transport for transport*. Brussels: EC

EC (European Commission), 2005. *The new SME definition: user guide and model declaration* [Online]. EU: Enterprise and Industry Publications. Available from: http://ec.europa.eu/enterprise/policies/sme/files/sme_definition/sme_user_guide_en.pdf [Accessed 26th August 2015].

Ecoinvent Centre, 2007. *Ecoinvent version 2* [Online]. Available from: <http://www.ecoinvent.org/database/database.html>

Ecolane Consultancy, 2007. *Travelfootprint* [Online]. Available from: <http://travelfootprint/> [Accessed: 2nd February 2012].

ECOTEC Research and Consulting, 2000. *Report on SMEs and the environment* [Online]. Brussels: European Commission Directorate General Environment. Available from: <http://www.europa.eu.int/comm/environment/sme/index.htm> [Accessed 19th March 2010].

Education Today 2013. Applications for online degrees up by 59% [Online]. *Education Today*, April, p.4. Available from: <http://content.yudu.com/A25i18/EducationApr2013/resources/index.htm?referrerUrl=http%3A%2F%2Fwww.education-today.co.uk%2F> [Accessed 23rd November, 2014].

EHS (Environment and Heritage Service), 2000. *Guidelines for the company reporting on waste* [Online]. Available from: http://www.doeni.gov.uk/niea/waste_report_guidelines_pp.pdf [Accessed 15th August 2012].

Elkington, J., 1998. Partnerships from cannibals with forks: the triple bottom line of 21st century business, *Environmental quality management*, 8(1), pp.37-51.

Emerson, R. M., 1976. Social exchange theory. *Annual review of sociology*, 2, pp.335–362.

Emmenegger, M. F., Heck, T. & Jungbluth, N., 2003. Erdgas. Sachbilanzen von Energiesystemen, *Ecoinvent report version*, 2.

ERM (Environmental Resources Management), 2010. *Company GHG emissions reporting – a study on methods and initiatives* [Online]. UK: ERM Available from: http://ec.europa.eu/environment/pubs/pdf/ERM_GHG_Reporting_final.pdf [Accessed 26th August 2015].

EU Regulation, 2013. *Commission Regulation (EU) No 617/2013 of 26th June 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for computers and computer servers* [Online]. Available from: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32013R0617> [Accessed 15th January 2014].

Fairman, R. & Yapp C., 2005. Enforced self-regulation, prescription, and conceptions of compliance within small businesses: the impact of enforcement. *Law and policy*, 27(4), pp.491-519.

Faist E. M., Heck, T. & Jungbluth, N., 2003. Erdgas. Sachbilanzen von Energiesystemen. Final report No. 6 ecoinvent 2000. CH: Swiss Centre for LCI, PSI. Dübendorf and Villigen. Cited in: *SIMAPRO 7 classroom*, PRé consultants. Netherlands: Amersfoort.

Fan, W. & Yan, Z., 2010. Factors affecting response rates of the web survey: a systematic review. *Computers in human behaviour*, 26(2), pp.132-139.

Fanshawe, T., 2000. The interrelationship between environmental regulators, small and medium sized enterprises and environmental help organisations'. In: *Small and medium-sized enterprises and the environment: business imperatives*, Hillary, R., ed. Sheffield: Greenleaf Publishing Ltd.

Farrant, L., & Le Guern, Y., 2012. Which environmental impacts for ICT?-LCA case study on electronic mail. In: *Electronics Goes Green 2012+ (EGG)*, 9-12 September 2012 Berlin, pp.1-5, IEEE, 2012.

Finkbeiner, M., 2009. Carbon footprinting – opportunities and threats. *The international journal of life cycle assessment*, 14, pp.91-94.

Finkbeiner, M., ed., 2011. *Towards life cycle sustainability management*. Heidelberg: Springer ISBN: 978-94-007-1898-2.

Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D. & Suh, S., 2009. Recent developments in life cycle assessment. *Journal of environmental management*, 9, pp.1-21.

Fishbein, B. K., McGarry, L. S. & Dillon, P. S., 2000. *Leasing: a step toward producer responsibility* [Online]. Available form: <http://www.informinc.org/pages/research/waste-prevention/reports/report-leasing-a-step-toward-producer-responsibility.html> [Accessed 16th February 2010].

Fisher, K., Geenen, J., Jurceic, M., McClintock, K. & Davis, G., 2009. Applying asset-based community development as a strategy for CSR: a Canadian perspective on a win-win for stakeholders and SMEs. *Business ethics: a European review*, 18(1), pp.66-81.

Flyvbjerg, B., 2011. Case study. In: *The SAGE handbook of qualitative research*. 4th ed. Thousand Oaks, CA: Sage, pp. 301-316.

Fowler, F. J., Jr., 1993. *Survey research methods: applied social science research methods series, vol. 1*. California: Sage Publications.

Fox, R. J., Crask, M. R. & Kim, J., 1988. Mail survey response rate a meta-analysis of selected techniques for inducing response. *Public opinion quarterly*, 52(4), pp.467-491.

Frankl, P. & Rubik, F., 1999. *Life cycle assessment in industry and business adoption patterns, applications and implications*. Germany: Springer-Verlag Berlin Heidelberg.

Fricker, S., Galesic, M., Tourangeau, R. & Yan, T., 2005. An experimental comparison of web and telephone surveys. *Public opinion quarterly*, 69(3), pp.370-392

Freight line solutions, 2013. *I need to transport art or antiques* [Online]. Available from: <https://www.freightlink.co.uk/knowledge/articles/i-need-transport-art-or-antiques-where-do-i-start> [Accessed: 2nd May 2016].

Frischknecht, R., Jungbluth, N., Althaus, H. J., Bauer, C., Doka, G., Dones, R., Hirschier, R., Hellweg, S., Humbert, S., Kollner, T., Loerincik, Y., Margni, M. & Nemecek, T., 2007. *Implementation of life cycle impact assessment methods. Ecoinvent report no. 3, v2.0*. Dübendorf: Swiss Centre for Life Cycle Inventories.

FSB (Federation of small businesses), 2007. *Social and environmental responsibility and the small business owner* [Online]. Available from: <http://www.fsb.org.uk/LegacySitePath/policy/assets/CSR%20Dec%202008.pdf> [Accessed: 10th March 2016].

Fuglestad, J. S., Shine, K. P., Berntsen, T., Cook, J., Lee, D. S., Stenke, A. & Waitz, I. A., 2010. Transport impacts on atmosphere and climate metrics. *Atmospheric environment*, 44(37), pp.4648-4677.

Gabel, H. L. & Sinclair-Desgagné, B., 2001. The firm, its procedures and win-win environmental regulations. In: *Frontiers of environmental economics*, Folmer, H. et al., ed. Cheltenham/Northampton: Edward Elgar. ISBN 1 84064 226 2

Gadenne, D.L., Kennedy, J. & McKeiver, C., 2009. An empirical study of environmental awareness and practices in SMEs. *Journal of business ethics*, 84, pp.45–63.

Gaidajis, G. & Angelakoglou, K., 2011. Screening life cycle assessment of an office used for academic purposes. *Journal of cleaner production*, 19(14), pp.1639-1646.

George, A. L. & Bennett, A., 2005. *Case studies and theory development in the social sciences*. USA: MIT Press.

Gerring, J., 2004. What is a case study and what is it good for? *American political science review*, 98(02), pp.341-354.

Gibson, T. & van der Vaart, H.J., 2008. *Defining SMEs: a less imperfect way of defining small and medium enterprises in developing countries* [Online]. Available from: <http://www.brookings.edu/research/papers/2008/09/development-gibson> [Accessed 15th December 2010].

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J. & Van Zelm, R. 2009. *ReCiPe 2000—A life cycle impact assessment method which compares harmonised category indicators at the midpoint and the endpoint level. First Edition, Report I: Characterisation*. Netherlands: Ministry of Housing, Spatial Planning and Environment (VROM).

- Gonzalez-Benito, J. & Gonzalez-Benito, O., 2005. Environmental proactivity and business performance: an empirical analysis, *Omega*, 33(1), pp.1-15.
- Goodall, C., 2009. *The green guide for business: the ultimate environment handbook for businesses of all sizes*. London: Profile Books Ltd.
- Göritz, A. S., 2006. Incentives in web studies: Methodological issues and a review. *International journal of internet science*, 1(1), pp.58-70.
- Gössling, S., Broderick, J., Upham, P., Ceron, J. P., Dubois, G., Peeters, P. & Strasdas, W., 2007. Voluntary carbon offsetting schemes for aviation: efficiency, credibility and sustainable tourism. *Journal of sustainable tourism*, 15(3), pp.223-248.
- Graedel, T.E., Allenby B.R. & Comrie, P.R., 1995. Matrix approaches to abridged life cycle assessment. *Environmental science and technology*, 29(3), pp.134-9.
- Graedel, T.E., 1997. Life-cycle assessment in the service industries. *Journal of industrial ecology*, 1(4), pp.57-70.
- Graedel, T.E., 1998. *Streamlined Life Cycle Assessment*. New Jersey: Prentice Hall.
- Graedel, T.E. & Saxton, E., 2002. Improving the overall performance of existing telecommunications facilities. *International journal of life cycle assessment*, 7(4), pp.219-24.
- Graedel, T.E., 2003. Greening the service industries. *The service industries journal*, 23(5), pp.48-64.
- Grant, D.B., Teller, C. & Teller, W., 2005. Hidden opportunities and benefits in using web-based business-to-business surveys. *International journal of marketing research*, 47(6), pp.641-666.
- Greenbaum, T.L., 2000. *Moderating focus groups a practical guide for group facilitation*. London: Sage.
- Greenlaw, C. & Brown-Welty, S., 2009. A comparison of web-based and paper-based survey methods: testing assumptions of survey mode and response cost. *Evaluation review*, 33(5), pp.464-480.
- Greenwise, 2013a. *Grants and funding* [Online]. Available from: <http://www.greenwisebusiness.co.uk/resources/green-grants-and-funding-16.aspx> [Accessed: 16th December 2013].
- Greenwise, 2013b. *Emissions measuring and reporting* [Online]. Available from: <http://www.greenwisebusiness.co.uk/resources/emissions-measuring-and-reporting-4.aspx> [Accessed: 4th September 2013].
- Groves, R. M., Cialdini, R. B. & Couper, M. P., 1992. Understanding the decision to participate in a survey. *Public opinion quarterly*, 56(4), pp.475-495.
- Guinée, J.B., 2002. *Handbook on life cycle assessment: operational guide to the ISO standards*. Dordrecht, Boston: Kluwer Academic Publishers

Gunningham, N. & Sinclair, D., 2002. *Leaders and laggards: next generation environmental regulation*. Sheffield: Greenleaf Publishing Ltd.

Heberlein, T. A. & Baumgartner, R., 1978. Factors affecting response rates to mailed questionnaires: a quantitative analysis of the published literature. *American sociological review*, pp.447-462.

Heerwegh, D. & Loosveldt, G., 2008. Face-to-face versus web surveying in a high internet coverage population: differences in response quality. *Public opinion quarterly*, 72, pp.836-846.

Heidrich, O. & Tiwary, A., 2013. Environmental appraisal of green production systems: challenges faced by small companies using life cycle assessment. *International journal of production research*, 51(19), pp.5884-5896.

Heneman, R.L., Tansky, J.W. & Camp, S.M., 2000. Human resource management practices in small and medium-sized enterprises: unanswered questions and future research perspectives. *Entrepreneurship: theory and practice*, 25(1), pp.11-26.

Herring, H. & Robin, R., 2007. Technological innovation, energy efficient design and the rebound effect. *Technovation*, 27(4), pp. 194-203.

Hill J. & Wright, L.T., 2001. A qualitative research agenda for small to medium-sized enterprises. *Marketing intelligence & planning*, 19(6), pp.432-443.

Hillary, R., 2000. *Small and Medium-sized Enterprises and the Environment: Business Imperatives*. Sheffield: Greenleaf Publishing Ltd.

Hillary, R., 2004. Environmental management systems and the smaller enterprise. *Journal of cleaner production*, 12(6), pp.561-569.

Hillary, R. & Burr, P., 2011. *Evidence-based Study into the Benefits of EMSs for SMEs*. London: Defra.

Hines, F. & Johns, R., 2001. Environmental supply chain management: evaluating the use of environmental mentoring through supply chains [Online]. Sustainability at the millennium: globalization, competitiveness and the public trust. *Ninth International Conference of Greening of Industry Network*, 21-25 January 2001. Bangkok. Available from: <https://gin.confex.com/gin/archives/2001/papers/190.pdf> [Accessed 26th August 2015].

HMG (Her Majesty's Government), 2011. *Implementing the climate change act 2008: The government's proposal for setting the fourth carbon budget: Policy statement* [Online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48081/1683-4th-carbon-budget-policy-statement.pdf [Accessed 11th April 2016].

HMSO (Her Majesty's Stationary Office), 2008. Climate change act 2008. UK: HMSO.

Hobbs, J., 2000. Promoting cleaner production in small and medium-sized enterprises. In: *Small and medium sized enterprises and the environment: business imperatives*, Hillary, R., ed. Sheffield: Greenleaf, pp. 148-157.

- Holland, L. & Gibbon, J., 1997. SMEs in the metal manufacturing, construction and contracting service sectors: environmental awareness and actions. *Eco-management and auditing*, 4, pp.7-14.
- Holmberg, J., 1999. Streamlined life-cycle assessment. *Journal of Industrial Ecology*, 3(1), pp.130-133.
- Homans, G.C., 1958. Social behaviour as exchange. *American journal of sociology*, 63(6), pp. 597-606.
- Hooi, K.K., Hassan, P. & Jami, N.A., 2011. Sustainable Education: an assessment of carbon footprint at UCSI University and proposed green campus initiative framework. *3rd International Conference on Information & Financial Engineering IPEDR* (12) IACSIT Press, Singapore, pp.342-347.
- Hunt, J., 2000. Environment, information and networks: how does information reach small and medium-sized enterprises?. In: *Small and medium-sized enterprises and the environment: business imperatives*, Hillary, R. (ed). Sheffield: Greenleaf Publishing Ltd.
- Hutt, R. W., 1979. The focus group interview: A technique for counselling small business clients. *Journal of small business management*, 17(1), pp.15-20.
- ICCA (International Congress and Convention Association), 2010. *Statistics report the international association meetings market* [Online]. Netherlands: ICCA. Available from: <http://www.iccaworld.com/searchsite.cfm?cx=010512806986151457630%3A69yazfikppk&cof=F%3A69yazfikppk&ie=UTF-8&spgid=250&q=statistics+report+2010&gbutton.x=0&gbutton.y=0&gbutton=Go> [Accessed 25th August 2015].
- IEMA (Institute of Environmental Management and Assessment), 2010. *Special report – GHG management and reporting* [Online]. Lincoln: Ruddocks Available from: https://www.iema.net/system/files/iema20ghg20report204.10.10_0.pdf [Accessed 26th August 2015].
- Ilomaki, M. & Melanen, M., 2001. Waste minimisation in small and medium-sized enterprises – do environmental management systems help? *Journal of cleaner production*, 9, pp.209-217.
- Isaksson, R. B., Garvare, R. & Johnson, M., 2015. The crippled bottom line-measuring and managing sustainability. *International journal of productivity and performance management*, 64(3), pp.334-355.
- ISO, 2006a. *Environmental management-life cycle assessment-principles and framework. Second Edition, EN ISO 14040*. London: ISO (International Standards Organisation).
- ISO, 2006b. *Environmental management-life cycle assessment-requirements and guidelines. First Edition, EN ISO 14044*. London: ISO (International Standards Organisation).
- ISO, 2006c. *Greenhouse gases - part 2: specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. EN ISO 14064-2*. London: ISO (International Standards Organisation).

Jones, J., 2013. *UK service industries: definition, classification and evolution*. London: Office for National Statistics.

Junnila, S., 2006a. Alternative scenarios for managing the environmental performance of a service company. *Journal of industrial ecology*, 10(4), pp.113-131.

Junnila, S., 2006b. Empirical comparison of process and economic input-output life cycle assessment in service industries. *Environmental science & technology*, 40(22), pp.7070-7076.

Kaenzig, J., Friot, D., Saadé M., Margni, M. & Jolliet, O., 2009. Using Life Cycle Approaches to Enhance the Value of Corporate Environmental Disclosures. *Business strategy and the environment*, 20(1), pp.38-54.

Kanuk, L. & Berenson, C., 1975. Mail survey and response rates: a literature review. *Journal of marketing research*, 12(4), pp.440–453.

Kaplowitz, M. D., Hadlock, T. D. & Levine, R., 2004. A comparison of web and mail survey response rates. *Public opinion quarterly*, 68, pp.94-101.

Kates, R.W., Parris, T.M. & Leiserowitz, A.A., 2005. What is sustainable development?. *Environment*, 47(3), p.8.

Kenny, T. & Gray, N. F., 2009. Comparative performance of six carbon footprint models for use in Ireland. *Environmental impact assessment review*, 29(1), pp.1-6.

Kiernan, N. E., Kiernan, M., Oyler, M. A. & Gilles, C., 2005. Is a web survey as effective as a mail survey? A field experiment among computer users. *American journal of evaluation*, 26(2), pp.245-252.

Kolk, A., Walhain, S. & van de Weteringen, S., 2001. Environmental reporting by the fortune global 250: exploring the influence of nationality and sector. *Business strategy and the environment*, 10(1), pp.15–28.

Krueger, R.A., 1998a. *Developing questions for focus groups*. Thousand Oaks, CA: Sage Publications, Inc.

Krueger, R.A., 1998b. *Moderating focus groups*. Thousand Oaks, CA: Sage Publications, Inc.

Krueger, R.A., 1998c. *Analysing and reporting focus group results*. Thousand Oaks, CA: Sage Publications, Inc.

Krueger, R.A. & Casey, M. A., 2008. *Focus groups: a practical guide for applied research*. 4th ed. Thousand Oaks, CA: Sage Publications, Inc.

Laird, J. D., 2007. *Feelings: the perceptions of self*. New York: Oxford University Press.

Lamming, R. & Hampson, J., 1996. The environment as a supply chain management issues. *British journal of management*, 7(Special Issue), pp.S45-S62.

Lawrence, S.R., Collins, E., Pavlovich, K. & Muruges, A., 2006. Sustainability practices of SMEs: the case of NZ. *Business strategy and the environment*, 15, pp 242-257.

- Lehmann, M. & Hietanen, O., 2009. Environmental work profiles-a visionary life cycle analysis of a week at the office. *Futures*, 41, pp.468–481.
- Lewis, H. & Demmers, M., 1996. Life cycle assessment and environmental management. *Australian journal of environmental management*, 3, pp.110-123.
- Lindeijer, E., Müller-Wenk, R. & Steen, B., 2002. *Impact assessment of resources and land use. Life cycle impact assessment: striving towards best practice*. Pensacola, Florida: SETAC.
- Linsky, A. S., 1975. Stimulating responses to mailed questionnaires. *Public opinion quarterly*, 39(1), pp.82–101.
- MacCrory, R., 2006. *Regulatory justice: making sanctions effective* [Online]. London: Cabinet Office. Available from: <http://webarchive.nationalarchives.gov.uk/20121212135622/http://www.bis.gov.uk/files/file44593.pdf> [Accessed 26th August 2015].
- Macgregor, R., Vrazalic, L., Carlsson, S., Bunker, D. & Magnusson, M., 2002. The impact of business size and business type on small business investment in electronic commerce: a study of Swedish small businesses. *Australasian journal of information systems*, 9(2), pp.31-39.
- Málovics, G., Csigéné, N.N. & Kraus, S., 2008. The role of corporate social responsibility in strong sustainability. *The journal of socio-economics*, 37(3), pp.907-918.
- Manfreda, K. L., Bosnjak, M., Berzelak, J., Haas, I., Vehovar, V. & Berzelak, N., 2008. Web surveys versus other survey modes: a meta-analysis comparing response rates. *Journal of the market research society*, 50(1), p.79.
- Marshall Report, 1998. Economic instruments and the business use of energy. Task force report, London: Stationary Office. Cited in: Revell, A., Stokes, D., & Chen, H., 2010. Small businesses and the environment: turning over a new leaf. *Business strategy and the environment*, 19, pp.273-288.
- Masoni, P., Sara, B., Scimia, E. & Raggi, A., 2004. VerDEE: a tool for adoption of life cycle assessment in small and medium sized enterprises in Italy. *Progress in industrial ecology, an international journal*, 1(1-3), pp.203-228.
- Masurel, E., 2007. Why SMEs invest in environmental measures: sustainability evidence from small and medium-sized printing firms. *Business strategy and the environment*, 16, pp.190-201.
- Maude, A., 2014. A sustainable view of sustainability?, *Geography*, 99, p.47.
- McCabe, S. E., 2004. Comparison of web and mail surveys in collecting illicit drug use data: a randomized experiment. *Journal of drug education*, 34(1), pp.61–72.
- McCann, A., 2010. *Quarterly Survey of Small Businesses in Britain, Q2, 26(2)* [Online]. City Print: OU. Available from: <http://www.open.ac.uk/business-school/research/quarterly-survey/reports> [Accessed 26th August 2015].
- McCann, A., 2011. *Special topic: information and computing technologies. Quarterly Survey of Small Businesses in Britain, Q1, 27(1)* [Online]. City Print: OU. Available from:

<http://www.open.ac.uk/business-school/sites/www.open.ac.uk.business-school/files/file/publications/download/2011-Q1.pdf> [Accessed 26th August 2015].

McKeiver, C. & Gadenne, D., 2005. Environmental management systems in small and medium businesses. *International small business journal*, 23(5), pp.513-537.

Merritt, J.Q., 1998. EM into SME won't go; attitudes, awareness and practices in the London borough of Croydon. *Business strategy and the environment*, 7(2), pp.90-100.

Millard, D., 2011. Management learning and the greening of SMEs: moving beyond problem-solving. *Zeitschrift für personalforschung*, 25(2), pp.178-195.

Mir, D. F., 2008. Environmental behaviour in Chicago automotive repair micro-enterprises (MEPs). *Business strategy & the environment*, 17(3), pp.194-207.

Mir, D.F. & Feitelson, E., 2007. Factors affecting environmental behaviour in micro-enterprises laundry and motor vehicle repair firms in Jerusalem. *International small business journal*, 25(4), pp.383-415.

Mohan, A., 2013. *New Coke bottle for U.K. is lightest 330-mL ever, Design technology investments and changes in the glass forming process by U.K. glass manufacturer results in 190g weight for 330 ml bottle* [Online]. Available from: <http://www.packworld.com/sustainability/source-reduction/new-coke-bottle-uk-lightest-330-ml-ever> [Accessed: 15th March 2014].

Mora, M. 2011. *Three popular online survey tool*. Available from: <http://www.relevantinsights.com/free-online-survey-tools#sthash.PrV1h5Ya.bR8OIiNiV.dpbs> [Accessed 13th August 2011]

Morgan, D.L., 1998a. *The focus group guidebook*. Thousand Oaks, CA: Sage Publications, Inc.

Morgan, D.L., 1998b. *Planning focus group guidebook*. Thousand Oaks, CA: Sage Publications, Inc.

Moss, J., Lambert, C.G. & Rennie, A.E.W., 2008. SME application of LCA-based carbon footprints. *International journal of sustainable engineering*, 1(2), pp.132-141.

Mowen, J. C., & Cialdini, R. B., 1980. On implementing the door-in-the-face compliance technique in a business context. *Journal of marketing research*, 17, pp.253-258.

Munn, P. & Drever, E., 2004. *Using questionnaires in small scale research*. Edinburgh: Scottish Centre for Research in Education, University of Glasgow ISBN 978-1860030864.

NERA, Economic Consulting & Enviros, 2006. *Policy options to encourage energy efficiency in the SME and public sectors*. London: HMSO.

NetRegs, 2002. *SME-nvironment survey 2002: How green are small businesses? netregs benchmarking survey of environmental awareness* [Online]. Available from: http://www.netregs.org.uk/pdf/netregs_benchmarking_survey_2002.pdf [Accessed 20th April 2016].

NetRegs, 2005a. *SME-nvironment survey 2005: England* [Online]. Available from: http://www.netregs.org.uk/pdf/2005_eng_summary_1197354.pdf [Accessed 20th April 2016].

NetRegs, 2005b. *SME-nvironment survey 2005: UK summary* [Online]. Available from: http://www.netregs.org.uk/pdf/2005_uk_summary_1197319.pdf [Accessed 20th April 2016].

NetRegs, 2007a. *SME-nvironment survey 2007: England* [Online]. Available from: http://www.netregs.org.uk/pdf/smenvironment2007eng_1857608.pdf [Accessed 20th April 2016].

NetRegs, 2007b. *SME-nvironment survey 2007: UK summary* [Online]. Available from: http://www.netregs.org.uk/pdf/smenvironment07uk_1856733.pdf [Accessed 20th April 2016].

NetRegs, 2009a. *SME-nvironment survey 2009: England* [Online]. Available from: http://www.netregs.org.uk/pdf/NetRegs_SME_Environment_2009_England_summary.pdf [Accessed 20th April 2016].

NetRegs, 2009b. *SME-nvironment survey 2009: UK summary* [Online]. Available from: http://www.netregs.org.uk/pdf/2005_uk_summary_1197319.pdf [Accessed 20th April 2016].

Newby, R., Watson, J. & Woodliff, D., 2003. Using focus groups in SME research: the case of owner-operator objectives. *Journal of developmental entrepreneurship*, 8(3), pp.237-246.

OECD (Organisation for Economic Co-operation and Development), 2005. *OECD SME and entrepreneurship outlook*. Paris: OECD. Available from: <http://www.oecd.org/cfe/smes/oecdsmehandentrepreneurshipoutlook-2005edition.htm> [Accessed 27th August 2015].

Ofgem (2011). *Typical domestic energy consumption figures. Factsheet 96*. Available from: <https://www.ofgem.gov.uk/ofgem-publications/76112/domestic-energy-consump-fig-fs.pdf> [Accessed 27th August 2015].

Olsen, S. B., 2009. Choosing between internet and mail survey modes for choice experiment surveys considering non-market goods. *Environmental and resource economics*, 44(4), pp.591-610.

ONS (Office of National Statistics), 2011a. *170 years of industrial change across England and Wales* [Online]. Available from: <http://www.ons.gov.uk/ons/rel/census/2011-census-analysis/170-years-of-industry/170-years-of-industrial-changeponent.html> [Accessed: 8th June 2013].

ONS (Office of National Statistics), 2011b. *Hours worked in the labour market* [Online]. Available from: <http://www.ons.gov.uk/ons/rel/lmac/hours-worked-in-the-labour-market/2011/index.html> [Accessed: 15th January, 2012].

ONS (Office of National Statistics), 2012. *Greenhouse gas (GHG) emissions* [Online]. Available from: <http://www.ons.gov.uk/ons/guide-method/compendiums/compendium-of-uk-statistics/the-environment/find-out-more/index.html#2> [Accessed 14th November 2012].

O'Regan, N., Ghobadian, A. & Gallea, D., 2006. In search of the drivers of high growth in manufacturing SMEs. *Technovation*, 26, pp.30-41.

Padgett, J.P., Steinemann, A.C., Clarke, J.H. & Vandenberg, M.P., 2008. A comparison of carbon calculators. *Environmental impact assessment review*, 28, pp.106-115.

Pallant, J., 2010. *SPSS Survival Manual: A step by step guide to data analysis using the SPSS program*. England: OUP. ISBN: 978-0335242399.

Palmer, J. & van der Vorst, R., 1996. Are standard systems right for SMEs?. *Eco-management and auditing*, 3, pp.91-96.

Palmer, J., 2000. Helping small and medium-sized enterprises improve environmental management: lessons from proactive small and micro firms. In: *Small and medium sized enterprises and the environment: business imperatives*, Hillary, R., ed. Sheffield: Greenleaf, pp. 325-342.

Pandey, D., Agrawal, M. & Pandey, J.S., 2011. Carbon footprint: current methods of estimation. *Environmental monitoring & assessment*, 178, pp.135-160.

Patton, M.Q., 2002a. *Qualitative research and evaluation methods*. Thousand Oaks, California: Sage.

Patton, M.Q., 2002b. Two decades of developments in qualitative inquiry: a personal experiential perspective. *Qualitative social work*, 1(3), pp.261-283.

Peattie, K. & Ringler, A., 1994. Management and the environment in the United Kingdom and Germany: A comparison. *European management journal*, 12(2), pp.216-225.

Petts, J., 2000. Smaller enterprises and the environment: organisational learning potential. In: *The business of greening*, Fineman, S., ed. London: Routledge.

Peytchev, A., 2009. Survey breakoff. *Public opinion quarterly*, 73(1), pp.74-97.

Polonsky, M. J., Grau, S. L. & Garma, R., 2010. The new greenwash? Potential marketing problems with carbon offsets. *International journal of business studies*, 18(1), pp.49-54.

Porter, M.E. & van der Linde, C., 1995. Green and competitive: ending the stalemate. *Harvard business review*, 73(5), pp.120-134.

Porter, S. R. & Whitcomb, M.E., 2003. The impact of contact type on web survey response rates. *Public opinion quarterly*, 67, pp. 579-588.

Porter, S. R. & Whitcomb, M. E., 2005. E-mail subject lines and their effect on web survey viewing and response. *Social science computer review*, 23(3), pp.380-387.

Porter, S. R. & Whitcomb, M. E., 2007. Mixed-mode contacts in web surveys paper is not necessarily better. *Public opinion quarterly*, 71(4), pp.635-648.

PRé Consultants, 2008a. *Introduction to LCA with SimaPro 7* [Online]. Amersfoort, the Netherlands: PRé Consultants. Available from: <http://www.simapro.de/uploads/media/SimaPro7IntroductionToLCA.pdf> [Accessed 27th August 2015].

- PRé Consultants, 2008b. *SimaPro database manual methods library* [Online]. Amersfoort, the Netherlands: PRé Consultants. Available from: <http://www.pre-sustainability.com/databases> [Accessed 27th August 2015].
- PRé Consultants, 2010. *SIMAPRO 7 Classroom*. Amersfoort, the Netherlands: PRé Consultants.
- PRé Sustainability, 2011. *The normalisation step in LCIA* [Online]. Available from: www.pre-sustainability.com/the-normalisation-step-in-lcia [Accessed 15th July 2011].
- Preuss, L., 2001. In dirty chains? Purchasing and greener manufacturing. *Journal of business ethics*, 34, pp.345-359.
- PYR (The Environmental Register of Packaging Ltd), 2013. *Packaging Weight Units*. [Online]. Available from: <http://www.pyr.fi/eng/forms/packaging-data-declaration-form/packaging-weight-units.html#5> [Accessed 21st May 2013].
- Ramus, C.A., 2000. Encouraging innovative environmental actions: what companies and managers must do?. *Journal of world business*, 37(2), pp.151-164.
- Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T. & Pennington, D. W., 2004. Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment international*, 30(5), pp.701-720.
- Renshaw, A., 2012. *Fuel market review 2012* [Online]. Available from: http://www.forecourtrader.co.uk/files/Fuel_Market_Review/FCT_Fuel_Mkt_Review_2012_low.pdf [Accessed: 15th August, 2012].
- Revell, A., 2003a. Environmental policy and the small firm: comparisons between Japan and the Netherlands. *Journal of environmental policy and planning*, 5(4), pp.397-413.
- Revell, A., 2005. Ecological modernisation in the UK: rhetoric or reality? *European environment*, 15, pp.344-361.
- Revell, A., 2008. The business case for sustainability: A small firm perspective. Thesis (PhD) Kingston University, UK. Access via: <http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.493139> [Accessed 27th August 2015].
- Revell, A. & Blackburn, R., 2007. The business case for sustainability? An examination of small firms in the UK's constructions and restaurant sectors. *Business strategy and the environment*, 16(6), pp.404-420.
- Revell, A. & Rutherford, R., 2003. UK environmental policy and the small firm: broadening the focus. *Business strategy and the environment*, 12(1), pp.26-35.
- Revell, A., Stokes, D. & Chen, H., 2010. Small businesses and the environment: turning over a new leaf. *Business strategy and the environment*, 19, pp.273-288.
- Rhodes, C., 2015. *Business statistics* [Online]. Available from: www.parliament.uk/briefing-papers/sn06152.pdf [Accessed July 14th 2015].

Ritchie, J. & Lewis, J., ed., 2012. *Qualitative research practice: A guide for social science students and researchers*. London: Sage Publications Ltd.

Rosenblum, J., Horvath, A. & Hendrickson, C., 2000. Environmental implications of service industries. *Environmental science & technology*, 34(22), pp. 4669-4676.

Rosenblum, J., 2001. *Give and take, quirk's marketing research review* [Online]. Available from: http://www.quirks.com/articles/article_print.asp?arg_articleid=705 [Accessed January 2011].

Roy, R., Potter, S. & Yarrow, K., 2008. Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems. *International journal of sustainability in higher education*, 9(2), pp.116-130.

Rutherford, R., Blackburn, R. & Spence, L., 2000. Environmental management in small firms: an international comparison. *International journal of entrepreneurial behaviour and research*, 6(6), pp.310-326.

Schaper, M., 2002. Small firms and environmental management, predictors of green purchasing in western Australian pharmacies. *International small business journal*, 20(3), pp.235-251.

Schlegelmilch, B. B. & Diamantopoulos, A., 1991. Prenotification and mail survey response rates: A quantitative integration of the literature. *Journal of the market research society*, 33(3), pp.243-255.

Schonlau, M., Ronald Jr, D. & Elliott, M. N. 2002. *Conducting research surveys via e-mail and the web* [Online]. USA: Rand Corporation. Available from: http://www.rand.org/pubs/monograph_reports/MR1480.html [Accessed 27th August 2015].

Seidel, M., Seidel, R., Tedford, D., Cross, R., Wait, L. & Hämmerle, E., 2009. Overcoming barriers to implementing environmentally benign manufacturing practices: strategic tools for SMEs. *Environmental quality management*, 18(3), pp.37-55.

Senderovitz, M., 2009. How are SMEs defined in current research? In: *Proceedings of AGSE*. AGSE.

Sgaard, V. & Madsen, S.O., 2007. The red queen and the environment reconciling public regulation and business strategy. *Business strategy and the environment*, 16, pp.430-441.

Shanks, R. & Kong, I., 2012. Thermoplastic starch. In: *Thermoplastic elastomers*, El-Sorbati, A. (ed). Europe: Intech, pp.95-116.

Shih, T. H. & Fan, X., 2008. Comparing response rates from web and mail surveys: A meta-analysis. *Field methods*, 20(3), pp.249-271.

Shin, E., Johnson, T.P. & Rao, K., 2012. Survey mode effects on data quality: Comparison of web and mail modes in a U.S. national panel survey. *Social science computer review*, 30(2), pp.212-228.

Shrake, S.O., Landis, A.E. & Bilec, M. M., 2011. Greening the service industries: A case study of a United States engineering consulting firm. In: *Sustainable Systems & Technology (ISSST), 2011 IEEE International Symposium*, Chicago IL.

- Shu, T. C., 2005. Comparing mail and web-based survey distribution methods: Results of surveys to leisure travel retailers. *Journal of travel research*, 43(4), pp.422–30.
- Simpson, M., Taylor, N. & Barker, K., 2004. Environmental responsibility in SMEs: does it deliver competitive advantage?. *Business strategy and the environment*, 13(3), pp.156–71.
- Sirkin, R. M., 2005. *Statistics for the social sciences*. 3rd ed. Thousand Oaks CA: Sage Publications Inc.
- Sitarz, D., 2008. *Greening your business: a hands-on guide to creating a successful and sustainable business*. USA: Nova Publishing Company.
- Slattery, P., 2009. The otus theory of hotel demand and supply. *International journal of hospitality management*, 28, pp.113–120.
- Steel, B., 1996. Thinking globally and acting locally? Environmental attitudes, behaviour and activism. *Journal of Environmental Management*, 47(1), pp.27-36.
- Stern, C. & Dietz, T., 1994. The value of environmental concern. *Journal of social issues*, 50, pp. 65-84.
- Stokes D. & Wilson N., 2006. *Small business management and entrepreneurship*. 5th ed. London: Thomson.
- Stone, L., 2006a. Limitations of Cleaner production Programmes as Organisational Change Agents. I. Achieving Commitment and On-going Improvement. *Journal of cleaner production*, 14, pp.1-14
- Stone, L., 2006b. Limitations of Cleaner production Programmes as Organisational Change Agents. II. Leadership, Support, Communication, Involvement and Programme Design. *Journal of cleaner production*, 14, pp.15-30.
- Strauss, A. & Corbin., J 1990. *Basics of qualitative research*. Newbury Park, CA: Sage.
- Studer, S., Tsang, S., Welford, R. & Hills, P., 2008. SMEs and voluntary environmental initiatives: a study of stakeholders' perspectives in Hong Kong. *Journal of environmental planning and management*, 51(2), pp.285-301.
- Suchard, R., Sapru, R. & Stewart, E., 2007. *Beyond neutrality: moving your company towards climate leadership* [Online]. San Francisco: Business for Social Responsibility. Available from: http://icarusfoundation.typepad.com/icarusblog/files/BSR_Beyond-Neutrality.pdf [Accessed on 27th August 2015].
- Sue, V. M. & Ritter, L. A., 2012. *Conducting online surveys*. London: Publications Ltd Sage.
- Sullivan, R. (ed), 2008. *Corporate responses to climate change: achieving emissions reductions through regulation, self-regulation and economic incentives*. Sheffield: Greenleaf Publishing Ltd.
- SWO (South West Observatory), 2008. *Small and medium-sized enterprises in SW England* [Online]. Available from: www.swo.org.uk/bem [Accessed 1st September 2009].

Taylor, H., 2000. Does internet research work? Comparing online survey results with telephone survey. *International journal of market research*, 42(1), pp.51-63.

Tilley, F., 1999a. The gap between environmental attitudes and the environmental behaviour of small firms. *Business strategy and the environment*, 8, pp.238-248.

Tilley, F., 1999b. Small-firm environmental strategy: the UK experience [Online]. Available from: <http://www.greenleaf-publishing.com/content/pdfs/gmi25till.pdf> [Accessed on 27th August 2015].

Tilley, F., Hooper, P. & Walley, L., 2003. Sustainability and competitiveness: are there mutual advantages for SMEs? In: *Competitive advantage in SMEs: organising for innovation and change*, Jones, O. & Tilley, F., eds. Chichester: John Wiley & Sons Ltd.

Todd, J. A. & Curran, M. A., eds., 1999. *Streamlined Life-Cycle Assessment Society of Environmental Toxicology and Chemistry (SETAC) 1999* [Online]. USA: SETAC North America Streamlined LCA Workgroup. Available from: <http://www.ce.cmu.edu/~hsm/lca2007/readings/streamlined-lca.pdf> [Accessed 27th August 2015].

Truell, A., Bartlett, J. E. & Alexander, M.W., 2002. Response rate, speed, and completeness: A comparison of internet-based and mail surveys. *Behaviour research methods, instruments and computers*, 34(1), pp.46-49.

Trusty, W. & Horst, S., 2005. LCA tools around the world. *Building design and construction*, 5, pp.12-16.

Tunnessen, W.W., 2000. The mentoring of small and medium-sized enterprises: insight from experiences in the United States. In: *Small and medium-sized enterprises and the environment: Business imperatives*, Hillary, R., ed. Sheffield: Greenleaf Publishing Ltd.

UK SIC (UK Standard Industrial Classification of Economic Activities), 2007. *UK Standard Industrial Classification of Economic Activities* [Online]. Basingstoke: Palgrave Macmillan. Available from: <http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/standard-industrial-classification/index.html> [Accessed 2nd October 2010].

UN (United Nations), 2008. *International standard industrial classification of all economic activities, revision 4* [Online]. Available from <http://unstats.un.org/unsd/class/family/family2.asp?Cl=27>. [Accessed 10th March 2010].

UNEP, 2002. *Global environmental outlook*, 3, Nairobi: UNEP [Online]. Available from: <http://www.unep.org/geo/GEO3/english/pdfs/prelims.pdf> [Accessed 12th April 2016]

Van Hoorn, Th. P., 1979. Strategic planning in small and medium-sized companies. *Long range planning*, 12(2), pp.84-91.

Van Selm, M. & Jankowski, N. W., 2006. Conducting online surveys. *Quality and quantity*, 40(3), pp.435-456.

Verheul, H., 1999. How social networks influence the dissemination of cleaner technologies to SMEs. *Journal of cleaner production*, 7, pp.213-219.

Vernon, J., Essex, S., Pinder, D. & Curry, K., 2003. The 'greening' of tourism micro-businesses: outcomes of focus group investigations in South East Cornwall. *Business strategy and the environment*, 12(1), pp.49-69.

Vickers, I, Vaze, P, Corr, L, Kasparova, E. & Lyon, F., 2009. *SMEs in a low carbon economy a report for BERR by the Centre for Enterprise and Economic Development Research*, 2009 [Online]. UK: Middlesex University. Available from: http://www.mdx.ac.uk/__data/assets/pdf_file/0013/22720/SME-in-a-low-carbon-economy.pdf [Accessed 25th August 2015].

Vogtländer, J. & Segers, M., 2011. *Fast Track LCA* [Online]. Available from www.ecocostsvalue.com/EVR/img/LCA%20Guide-IO2070_1011.pdf [Accessed 2nd May 2014]

Von Weizsacker, E., Lovins, A. & Lovins, H., 2006. *Factor four doubling wealth, halving resource use*. Oxon: Earthscan. ISBN: 978-1-85383-406-6.

Vos, J., 1998. Diagnosing constraints in knowledge of SMEs. *Technological forecasting and social change*, 58, pp.227-239.

Vyakarnam, S., Bailey, A., Myers, A. & Burnett, D., 1997. Towards an understanding of ethical behaviour in small firms. *Journal of business ethics*, 16(15), pp.1625-1636.

Walker, E. A., Redmond, J. L. & Giles, M. J., 2010a. Preface to Special Issue: Environmental Sustainability and Business. *International journal of business studies*, 18(1), pp.1-5.

Walker, E. A., Redmond, J. L. & Giles, M. J., 2010b. A proposed methodology to promote adoption of 'green' production by small firms. *International journal of business studies – special edition*, 18(1), pp.39-48.

Walker, H., Di Sisto, L. & McBain, D., 2008. Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *Journal of purchasing and supply management*, 14(1), pp.69-85.

Walker, B., Redmond, J., Sheridan, L., Wang, C. & Goeft, U., 2008. *Small and medium enterprises and the environment: barriers, drivers, innovation and best practice: a review of the literature* [Online]. Edith Cowan University, Australia: Small & Medium Enterprise Research Centre. Available from: http://perthregionnrm.com/media/3319/briefing_report_march_2008.pdf [Accessed 27th August 2015].

Ward, M. & Rhodes, C., 2014. *Small businesses and the UK economy standard note: SN/EP/6078* [Online]. London: House of Commons. Available from: <http://www.parliament.uk/briefing-papers/sn06078.pdf> [Accessed 27th August 2015].

Warren, C. A. B., 2002. Qualitative interviewing in Gubrium, J. F and Holstein, J. (eds.). *Handbook of interview research. Context & method*, Thousand Oaks, CA: Sage publications.

WCED (World Commission on Environment and Development), 1987. *Our common future* [Online]. Available from <http://www.un-documents.net/our-common-future.pdf> [Accessed January 14th 2010].

Wegener Sleeswijk, A., van Oers, L., Guinée, J.B., Struijs, J. & Huijbregts, M.A.J., 2008. Normalisation in product life cycle assessment: a LCA of the global and european economic systems in the year 2000. *Science of the total environment*, 390(1), pp.227-240.

WHATCAR, 2012. *Ford Focus key facts* [Online]. Available from: <http://www.whatcar.com/car-reviews/ford/focus-hatchback/1-0t-125-ecoboost-titanium-x-5dr/summary/69533> [Accessed: 18th May 2012].

Wiedmann, T. & Minx, J., 2007. A definition of 'carbon footprint'. In: *Ecological economics research trends*, Pertsova, C.C. (ed). New York: Nova Science Publishers.

Williams, S., 2007. A supplier development programme: the SME experience. *Journal of small business and enterprise development*, 14(1), pp.93-104.

Williamson D, Lynch-Wood G. & Ramsay J., 2006. Drivers of environmental behaviour in manufacturing SMEs and the implications for CSR. *Journal of business ethics*, 67, pp.317–30.

Wilson, C.D.H.; William, I.D. & Kemp, S., 2012. An evaluation of the impact and effectiveness of environmental legislation in small and medium-sized enterprises: Experiences from the UK. *Business strategy and the environment*, 21, pp.141–156.

WRAP (Waste and Resource Action Programme), 2005. *Reducing corrugated cardboard weight without compromising performance* [Online]. Available from: <http://www.wrap.org.uk/sites/files/wrap/15203-01%20Kite%20Packaging%20report.pdf>. [Accessed 15th April 2013].

WRI, (World Resource Institute) & WBCSB, (World Business Council on Sustainable Development), 2004. *Greenhouse gas (GHG) protocol* [Online]. USA: Hopkins Fulfilment Services. Available from: <http://www.ghgprotocol.org/standards/corporate-standard>, [Accessed 9th October 2011].

Wright, A., Kemp, S. & Williams, I., 2011. Carbon foot printing: towards a universally accepted definition. *Carbon management*, 2(1), pp.61-72.

Wrigley, S., 2008. Why do SMEs need to calculate their footprint? *The environmentalist*, 57, pp.16.

Yammarino, F. J., Skinner, S.J. & Childers, T.L., 1991. Understanding mail survey response behaviour. *Public opinion quarterly*, 55(4), pp.613–639.

Yin, R. K., 2009. *Case study research: design and methods*. 4th ed. Thousand Oaks, CA: Sage.

Yu, J. & Cooper, H., 1983. A quantitative review of research design effects on response rates to questionnaires. *Journal of marketing research*, 20(1), pp.36–44.

Zamagni, A., 2012. Life cycle sustainability assessment. *The international journal of life cycle assessment*, 17(4), pp.373-376.

Appendices

The appendices contained in this section are as follows:

Appendix A: Online survey questions

This appendix lists the questions used in the online survey emailed to service industry SMEs to ascertain information from owner-managers.

Appendix B: SME benchmarking and perceptions; supporting information

Appendix B provides supporting data to supplement the information presented in Chapter 4. The information includes the following:

- shows results from selected statistical tests (Tables 4-1 to 4-5) used in the analysis to support the findings for owner-managers on environmental business aspects
- provides details of the employees who participated in the roundtable discussion (Table 4-6) supporting the findings presented in Figures 4.10 and 4.11 respectively
- expresses findings from employees on the ease at which they can obtain Scope emission data (Tables 4-7 and 4-8), that is represented in Figures 4.10 and 4.11 respectively

Appendix C: Online survey, supporting information

Supplementary descriptive statistical data and information supporting the results from the online survey is presented in this appendix.

Appendix D: Data inventories for the three case studies

The data used to create the inventories for the packing company (Tables 5-1 to 5-3), the film (Tables 5-4 and 5-5) and the online distance learning companies (Tables 5-6 to 5-8) are provided in this appendix.

Appendix E: Characterised and normalised results using ReCiPe midpoint (H) (E), for the three case studies

The results from the assessments are presented for the packing company (Table 6-1); the film (Table 6-2) and the online distance learning company (Table 6-3) in this appendix.

Appendix A

Questions used in the online survey

A. Your Business:

1. What sector best describes your business activity?

2. How would you describe your business premises?

- Rented
- Leased
- Owner/Occupier
- Other

3. What is the approximate size of your business floor space [square metres]?

4. How many people do you employ?

- Full-time:
- Part time:

B. Your Energy Use

5. Electricity: What is your annual electricity consumption *(please leave blank if this energy use is not applicable?)*

- Less than 8,000 kWh
- Between 8,001 and 10,000 kWh
- Between 10,001 and 12,000 kWh
- Greater than 12,001 kWh
- I do not know my annual consumption

6. Gas: What is your annual gas consumption *(please leave blank if this energy use is not applicable?)*

- Less than 1,880 kWh
- Between 1,881 and 2,101 kWh
- Between 2,102 and 2,212 kWh

- Greater than 2,213 kWh
- I do not know my annual consumption

7. Coal: How much coal do you use annually *(please leave blank if this energy use is not applicable?)*

- What is your annual coal consumption
- What is your unit of measurement

8. Oil: How much oil do you use annually *(please leave blank if this energy use is not applicable?)*

- What is your annual oil consumption
- What is your unit of measurement e.g. litres

9. Other Energy Sources: Do you use renewable resources to generate energy?

- None
- Wind Energy
- Geothermal
- Hydro Energy *(use of water)*
- Bio-Energy *(use of plant material/wood)*
- Solar
- Other *(please specify in the space provided)*

10. What is your annual renewable energy consumption [please include units of measurement] *(please leave blank if not applicable?)*

- Wind Energy
- Geothermal
- Hydro Energy *(use of water)*
- Bio-Energy *(use of plant material/wood)*
- Solar

11. Is the response to your annual energy consumption estimates *(please respond to all that apply?)*

- Electricity

- Gas
- Coal
- Oil
- Renewable Energy

The responses options given were as follows:

Yes, estimated

No, not estimated

C. Your Transport Use

12. Road Travel: Do you use road transport for business purposes?

The response options given were as follows:

Yes

No

13. If YES please provide your estimated annual use of fuel and include the unit of measurement (please leave this section blank if not applicable)

- Petrol
- Diesel
- LPG
- CNG
- Other (please specify)

14. If you DO NOT have details of the quantities of fuel used, please can you give your annual estimated expenditure in £s for fuel purchased (please leave blank if you do not know)

- Petrol (£)
- Diesel (£)
- LPG (£)
- CNG (£)
- Other (please specify) (£)

15. Do the figures provided for road travel include the use of personal transport (vehicles owned by you and not the company) for business purposes (please leave blank if you do not know)

The response options given were as follows:

Yes

No

16. If NO can you estimate the total amount of fuel used in personal transport for business [please show the quantities with a unit of measurement OR an estimated cost in £s] (please leave blank if you do not know)

- Quantity (please include unit of measurement) OR
- Cost (please estimate in £s)

17. Air Travel: Do you use air travel for business purposes?

The response options given were as follows:

Yes

No

18. If YES how many of the following flights do you take annually (please leave this section blank if not applicable)

- Domestic Flights (Between UK Airports)
- Short Haul Flights (European Destinations)
- Long Haul Flights (Non-European Destinations)

19. Train Travel: Do you use train travel for business purposes?

The response options given were as follows:

Yes

No

20. If Yes to train travel (please leave this section blank if not applicable?)

- What is your most common train journey
- How many times a year do you make this journey

21. Employee Travel: Do employees use non-company owned vehicles for business purposes?

The response options given were as follows:

Yes

No

I do not know

22. If YES can you estimate the total annual distance travelled by employees in non-company vehicles (please leave blank if you do not know)

- Total annual distance travelled (please specify units)

23. If NO and the employees use company owned vehicles for business purposes can you estimate the total annual distance travelled (please leave blank if you do not know)

- Total annual distance travelled (please specify units):

D. Your Business Activities

24. Equipment and Machinery: Has your business any powered equipment or machinery: for example, printers, computers, microwave ovens, welding equipment, pumps, conveyors, motors etc

The response options were:

Yes

No

I do not know

25. If YES please can you provide a brief description and numbers of equipment and/or types of machinery in the space provided below; (please refer to the example for guidance) Example: 2, HP Laser Jet B/W printers; 1, 27-inch iMac etc

26. Business Waste Disposal: Please give details of any waste you dispose of that is related to your business activity for a typical week Do you RECYCLE any of the following:

- Printed Paper
- Food
- Batteries
- Plastics
- Glass

- Other Paper
- Cardboard
- Aluminum Cans

The response options were:

Yes

No

I do not know

27. Do the LOCAL AUTHORITY pick-up and take away any of the following business waste?

- Printed Paper
- Food
- Batteries
- Plastics
- Glass
- Other Paper
- Cardboard
- Aluminum Cans

The response options were:

Yes

No

I do not know

28. What is the quantity of the business waste that is disposed for the week [please give the units as kg/week or quantity and a description]; (please refer to examples for guidance).

Example I: Printed Paper 15 A4 Sheets or Example II: 2 Magazines or Example III: Printed Paper 1 kg/week OR leave blank if you do not know and go to the next question

- Printed Paper:
- Food:
- Batteries:
- Plastics:
- Glass:
- Other Paper:
- Cardboard:

- Aluminum Cans:
- Other (*please specify*)
- Other (*please specify*)
- Other (*please specify*)

E. Reporting Your Carbon Emissions

29. What percentage of carbon emissions in the UK do you think are produced by SMEs?

- Less than 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- Greater than 60%

30. Do you think it should be made mandatory for SMEs to report their carbon emissions?

The response options were:

Yes

No

I do not know

31. If YES please indicate the main reason why you think it should be made mandatory

- Enhances skills and improves knowledge in SMEs
- Improves the economic condition of SMEs
- Demonstrates environmental responsibility
- To stay in business
- Reduces secondary air pollutants e.g. ozone
- Reduces my carbon footprint
- Impact of climate change
- I do not know

32. If NO please indicate the main reason why you think it should not be made mandatory

- Lack of specialist staff

- Insufficient environmental benefits
- Changing economic climate alters the priority of carbon emissions
- Insufficient economic benefits
- Perceived costs for implementation and maintenance
- Poor quality of information
- Lack of business/industry affirmation
- I do not know

33. What do you think the reporting of carbon emissions should be based upon (*please provide a response to all in the list*)

- Employee numbers
- Industrial sector
- Amount of energy used
- Floor space

The response options were:

Disagree

Strongly agree

No opinion

Strongly disagree

Agree

34. If the government makes the reporting of carbon emissions mandatory for SMEs what data could you currently provide figures on?

- Distances travelled in vehicles owned by the company
- Commuting distance(s) of employee(s)
- Distance(s) for employee(s) business travel (using transport not owned by the business)
- Amount of electricity used by the business
- Amount of business/office waste generated but managed by another organisation
- Transportation distance of the business' waste by another organisation
- Production and manufacture of materials used by the business for instance, paper, printers
etc

The response options were:

Yes, could provide data

No, could not provide data

I do not know

35. What would ensure you reported your carbon emissions (*please provide a response for all drivers listed*)

- Risk of prosecution
- Improved environmental performance
- Access to new markets
- Government funding and support
- Motivates workforce
- Ensure compliance

The response options were:

Disagree

Strongly agree

No opinion

Strongly disagree

Agree

Appendix B

Table 4-1: Findings from Chi square test for independence used to determine the associations between the size of the company and the availability and accessibility of scope activity data

Scopes	Test	Valid cases (N)	df	Symmetric measure (Phi)	P value	Comments
<i>Scope 1</i>	Fisher's exact test	60	1	-0.18	0.23	Not significant
<i>Scope 2</i>	Fisher's exact test	62	1	-0.18	0.17	Not significant
<i>Scope 3</i>						
<i>Commuting distances of employees</i>	With Yates correction factor	61	1	-0.84	0.69	Not significant
<i>Business travel</i>	Fisher's exact test	60	1	-0.12	0.41	Not significant
<i>Business waste</i>	With Yates correction factor	52	1	-0.22	0.19	Not significant
<i>Transportation of business waste</i>	Fisher's exact test	50	1	-0.28	0.06	Not significant
<i>Production and Manufacture of materials used by the businesses</i>	Fisher's exact test	52	1	-0.11	0.56	Not significant

Table 4-2: Findings from Chi square test for independence used to determine the associations between the type of business premises from which the service operates and the availability and accessibility of scope activity data

Scopes	Test	Valid cases (N)	df	Symmetric measure (Phi)	P value	Comments
<i>Scope 1 & 2</i>					Not valid	Expected frequencies < 5 in 25% of cells
<i>Scope 3</i>						
<i>Commuting distances of employees</i>	Fisher's exact test	61	1	0.002	1.00	Not significant
<i>Business travel</i>	Fisher's exact test	60	1	0.16	0.35	Not significant
<i>Business waste</i>	Fisher's exact test	52	1	-0.05	0.76	Not significant
<i>Transportation of business waste</i>					Not valid	Expected frequencies less than 5 in 25% of cells
<i>Production and Manufacture of materials used by the businesses</i>	Fisher's exact test	52	1	-0.26	0.10	Not significant

Table 4-3: Findings from Chi square test for independence used to determine the associations between the size of the company and providing quantifiable waste data

Business waste	Test	Valid cases (N)	df	P value	Symmetric measure (Phi)	Comments
Paper	With Yates correction	69	1	0.87	-0.05	Not significant
Batteries	Fisher's exact test	69	1	0.75	-0.07	Not significant
Metal	Fisher's exact test	69	1	1.00	-0.02	Not significant
Plastics	Fisher's Exact Test	69	1	0.16	-0.20	Not significant
Cardboard	Fisher's exact test	69	1	1.00	0.03	Not significant
Food & glass				Not valid		In 50% of cells expected frequencies < 5

Table 4-4: Findings from Chi square test for independence used to determine the associations between the type of business premises and providing quantifiable waste data

Business waste	Test	Valid cases (N)	df	P value	Symmetric measure (Phi)	Comments
Paper	Pearson Chi-Square	69	2	0.89	0.06	Not significant
Cardboard	Pearson Chi-Square	69	2	0.30	0.19	Not significant
Food & glass				Not valid		In 50% of the cells expected frequencies < 5
Batteries, plastics & metal				Not valid		In 33% of the cells expected frequencies < 5

Table 4-5: Findings from Mann Whitney U-Test used to determine if there are significant differences between the scale of the enterprise and the total amount of GHG emissions produced for Scopes 1, 2 & 3

Scopes	Median (Md)	Values				Comments
		U	Z	r	p	
1	< 50 employees = 346, n = 25; ≥ 50 employees < 250 = 408, n = 19	162	-1.85	0.28	0.06	Not significant
2	< 50 employees = 3563, n = 24; ≥ 50 employees < 250 = 5347, n = 17	62	-4.04	0.63	< 0.001	Significant
3	< 50 employees = 5619, n = 40; ≥ 50 employees < 250 = 24604, n = 27	158	-4.88	0.60	< 0.001	Significant

Table 4-6: Socio-economic profile for employees from service industries who participated in the roundtable discussion

Participants	Gender	Age	Education	SIC (2007)
1	F	45 to 54	First degree	G
2	M	22 to 34	University higher degree	M
3	M	45 to 54	University higher degree	M
4	M	55 to 64	Professional/vocational	L
5	F	45 to 54	Professional/vocational	M
6	M	35 to 44	Professional/vocational	J
7	M	35 to 44	First degree	M

Table 4-7: Responses from roundtable discussion participants on the collating of Scope 1 & 2 emissions data using a seven-point semantic scale

Scopes 1 & 2	Emissions sources	Employee #1	Employee #2	Employee #3	Employee #4	Employee #5	Employee #6	Employee #7
Scope 1	Fuel combustion	QH (<i>Quite Hard</i>) (3)	E (<i>Easy</i>) (6)	E (<i>Easy</i>) (6)	E (<i>Easy</i>) (6)	E (<i>Easy</i>) (6)	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)
	Emissions from equipment	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)	VH (<i>Very Hard</i>) (1)	QE (<i>Quite Easy</i>) (5)	VH (<i>Very Hard</i>) (1)
	Business travel in company cars	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)	VE (<i>Very Easy</i>) (7)	QE (<i>Quite Easy</i>) (5)	E (<i>Easy</i>) (6)	E (<i>Easy</i>) (6)	E (<i>Easy</i>) (6)
	Business travel in ancillary company vehicles, e.g. vans, lorries etc	QH (<i>Quite Hard</i>) (3)	E (<i>Easy</i>) (6)	E (<i>Easy</i>) (6)	QH (<i>Quite Hard</i>) (3)	E (<i>Easy</i>) (6)	QE (<i>Quite Easy</i>) (5)	E (<i>Easy</i>) (6)
Scope 2	Purchased electricity, steam or heat	VE (<i>Very Easy</i>) (7)	VE (<i>Very Easy</i>) (7)	VE (<i>Very Easy</i>) (7)	QE (<i>Quite Easy</i>) (5)	E (<i>Easy</i>) (6)	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)

Table 4-8: Responses from roundtable discussion participants on the collating of Scope 3 emission data using a seven-point semantic scale

Emission sources	Employee #1	Employee #2	Employee #3	Employee #4	Employee #5	Employee #6	Employee #7
Business travel in non-company-owned vehicles e.g. trains/rental cars	H (<i>Hard</i>) (2)	QE (<i>Quite Easy</i>) (5)	QH (<i>Quite Hard</i>) (3)	QE (<i>Quite Easy</i>) (5)	QE (<i>Quite Easy</i>) (5)	QH (<i>Quite Hard</i>) (3)	N (<i>Neither</i>) (4)
Water use & waste water treatment	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	H <i>Hard</i> (2)	QH <i>Quite Hard</i> (3)	N <i>Neither</i> (4)	N <i>Neither</i> (4)	VH <i>Very Hard</i> (1)
Employee commuting in vehicle not owned by the business e.g. light rail, train, buses & employee cars	H (<i>Hard</i>) (2)	QE (<i>Quite Easy</i>) (5)	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	QH (<i>Quite Hard</i>) (3)	QH (<i>Quite Hard</i>) (3)	N (<i>Neither</i>) (4)
Production or manufacture of materials and resources used by the business, such as furniture, paper, equipment	H (<i>Hard</i>) (2)	VH (<i>Very Hard</i>) (1)	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	VH (<i>Very Hard</i>) (1)
Incineration of office waste or disposal in landfill when facilities are not owned by the business	VH (<i>Very Hard</i>) (1)	QH (<i>Quite Hard</i>) (3)	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	VH (<i>Very Hard</i>) (1)
Outsourced activities such as shipping, courier services & printing services	H (<i>Hard</i>) (2)	H (<i>Hard</i>) (2)	H (<i>Hard</i>) (2)	QH (<i>Quite Hard</i>) (3)	H (<i>Hard</i>) (2)	N (<i>Neither</i>) (4)	VH (<i>Very Hard</i>) (1)

Appendix C

Descriptive analysis supporting the results presented from the online survey in Chapter 4.

Profile of the service industry

Sixty-nine owner-mangers from service industry SMEs completed the online survey, producing a viable response rate of 23%. In relation to the scale of the surveyed businesses, the sole trader represented 14% of the responses; micro, 45%; small, 29% and medium, 12%. The micro businesses employing between one to nine employees dominated. Ten industrial classifications were represented in the survey as seen in Figure C-1. The three main classifications were professional, scientific and technical activities (41%), wholesale retail and trade repair (19%) and information and communication (12%).

The professional, scientific and technical section embraced a wide range of activities from advertising to scientific research through to engineering activities (Badel, 2011). The common factor with these activities is that they require a high degree of training and specialist knowledge and reflects the increasing *tertiarisation* of the working environment.

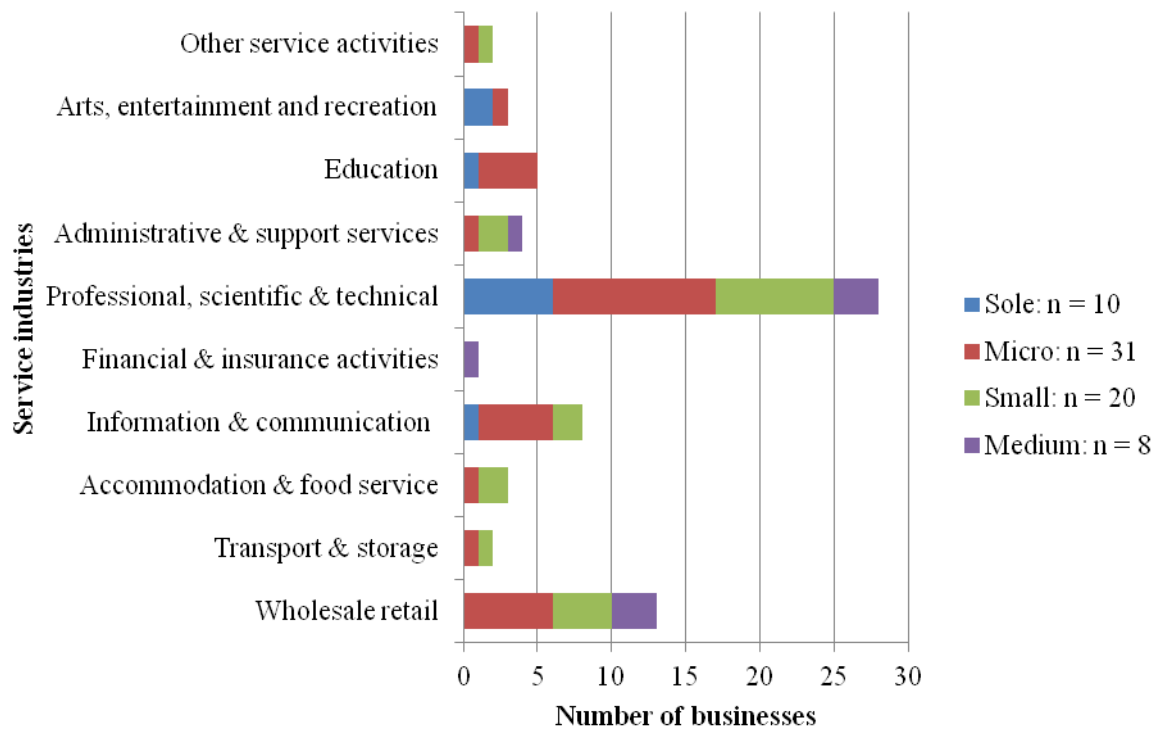


Figure C-1: Economic activities of the surveyed businesses in relation to size (n=69)

The premises presented to the respondents were rented; leased; owner-occupied or other. The differentiation between rented and leased premises was undertaken to discern among businesses; those who were sited in premises that had no set period of residence and those who had a set period of residence with fixed terms (see Figure C-2).

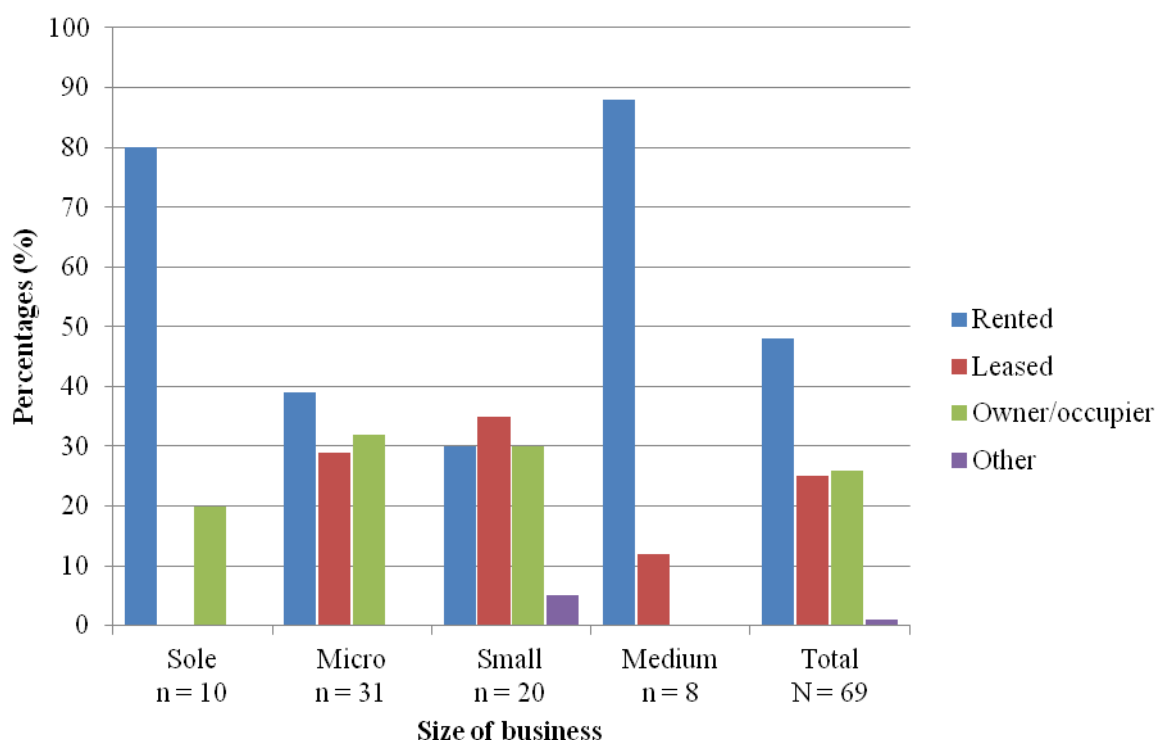


Figure C-2: Types of premises used by the surveyed businesses

About half of businesses reported that they rented their premises (48%) and a further 25% were leaseholders, the remainder were either owner-occupiers (26%) or other (1%). Rental was the preferred option for sole, micro and medium businesses however, for small businesses the preference was for lease premises with over a third (35%) reporting this as a status.

Energy use

To determine an energy profile for the surveyed businesses; the types of energy used; their annual consumption and whether the figures were estimated was explored. The two main energy sources used by the businesses were gas and electricity, which was used by 42% and 52% of the services respectively (see Figures: C-3 and C-4).

Coal was not used by any of the services who responded; oil was used by 4% of businesses as a fuel source for heating; averaging 3,200 litres; ranging from a maximum of 6,000 litres to a minimum of a 1,000 litres. The former value was the main fuel source for a micro business employing five employees classified as a professional, scientific and technical service involved in the testing and analysis of gases. The latter, was a sole trader, an owner-occupier whose economic activity was reported as in the information and communications sector.

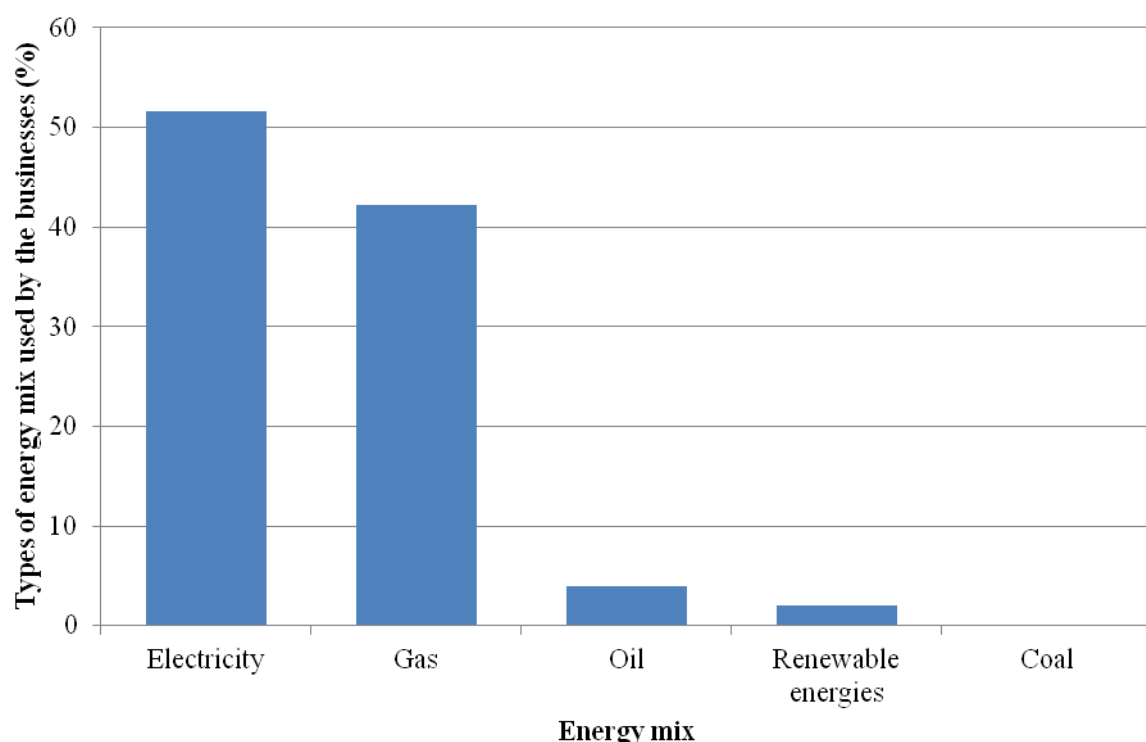


Figure C-3: Types of energy used by the businesses to provide power, heating and lighting

Renewable energy was used by 2% of the sector. This equated to three respondents; one was a medium professional, scientific and technical service business, and had employed both solar and hydro as part of their energy mix which contributed to 4,120 kW of their annual energy consumption. The other two respondents were employed under the professional scientific and technical sector and both were from the field of environmental consultancy and the micro reported using bio-energy; the small business, wind to generate energy.

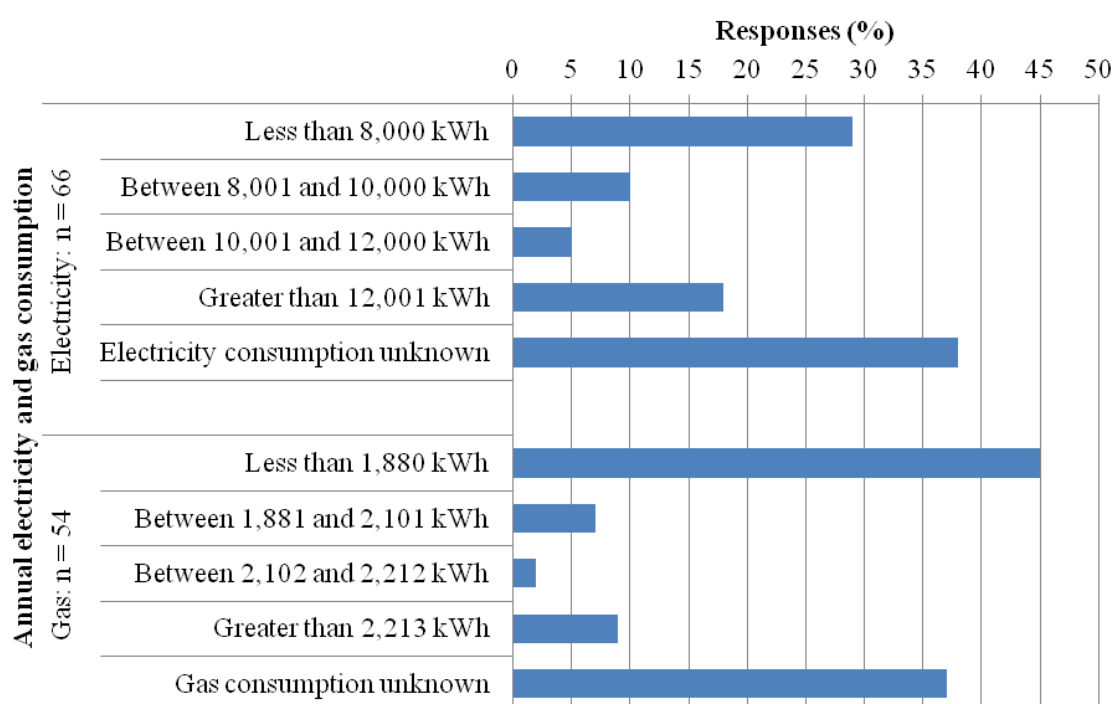


Figure C-4: Annual consumption for the main two energy sources reported by the surveyed businesses

The respondents, who used electricity nearly a third (29%), used less than 8,000 kWh and nearly a half (45%) used less than 1,880 kWh of gas. The annual consumption of electricity and gas was unknown by a just over a third of the services (38% and 37% respectively). It was hypothesised that as 73% of respondents were renting or leasing their premises (see Figure 4-2) whereby energy consumption is incorporated into monthly fees there would be no motivation to know their energy usage, as any reductions are not beneficial to them directly.

The significance of the type of business premises relative to whether the energy mixes readings were estimated (see Figures C-4 and C-5) was tested using Chi Square. The main result indicated there was no significant association between the types of the business premises from which the firms traded and providing estimated electricity consumption values, X^2 (using Fisher's Exact Probability Test) (1, $n = 48$); $p = 0.52$, $\phi = -0.12$. In terms of providing estimated gas consumption figures relative to the type of business premises; this was undertaken however, using the Chi Square test and adhering to no cells with expected counts of less than 5, 50% of cell sizes were not greater than 5. Subsequently, based upon this stringent rule the results from estimated gas consumption were inconclusive.

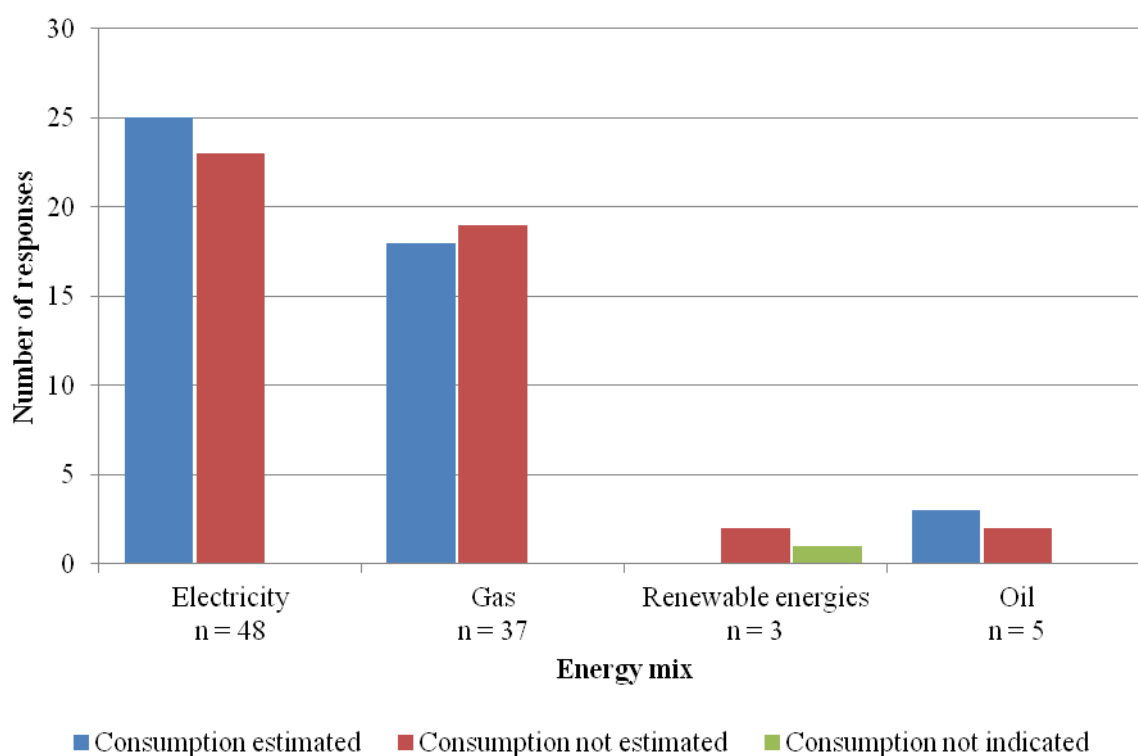


Figure C-5: Responses from the businesses to reported energy consumption in terms of estimated figures

Business transport

The main transport options that were considered for business use were road, rail and air. Relative to each of these modes of travel, over half, (52%), of the sector used road travel in their business dealings; just over a quarter used rail, (26%), and (22%) reported air travel. Road transport was the main mode of travel based upon business trips/annum. In terms of road travel, the main types of fuel used were petrol and diesel by 34% and 63% respectively. LPG and CNG were not used by any of the responding businesses and 3% used another fuel source. The annual average distance travelled by the businesses using road for business purposes was ~1,800 miles, this equated to

~95litres of transport fuel. The calculation was modelled upon the Ford Fiesta the most popular company car in 2011, which travelled at ~19 miles per litre.

Air travel for business purposes was used by nearly a quarter of the respondents. Flights were detailed into domestic, short and long haul flight options. The findings showed the average annual distance travelled on domestic flights for business purposes was 3,500 km; short-haul 9,300 and long-haul 25,000 km. The median number of domestic flights taken by the respondents, was six domestic, five short-haul, and two long-haul. On closer examination of the flight data, short-haul flights for business was used by 44% of the reporting firms and business domestic flights, 42%.

Train travel for business purposes was used by 26% of businesses. To ascertain the contribution of this mode of travel to the business activities of the sector, the respondents were asked what their most common journey was and how many times a year they made this particular journey. The most common journey was travel to London, a median value of six times a year. The average distance travelled by train for business a year was 5,400 km.

Waste activities

The current available figures for waste produced in England from industrial and commercial activities, as estimated from the *Reconcile Project* is 43.8 million tonnes each year (DEFRA, 2015), which impacts upon the environment. The reduction of waste not only benefits the environment but also, results in financial savings for a business (DEFRA, 2013c). The results are based upon 69 businesses and as presented in Figure C-6 show that cardboard was recycled by 86% of the businesses and glass is least likely to be recycled with 54% not recycling this waste. The findings also revealed that for this sector waste provision by the local authority (LA) was provided to 30% of businesses; for 52% of businesses the LA do not take away their business waste and 18% were uncertain of their business waste provision.

The conscious recycling of waste can create greater waste awareness. The association between those businesses that recycled their business waste and the ability to provide quantifiable waste data was tested with the Chi-square test for independence using *Fisher's Exact Probability Test* (Pallant, 2010). The main findings established a significant association between the recycling of plastics ($X^2 (1, n = 63), p = 0.006, phi = 0.36$) and metals ($X^2 (1, n = 58), p = 0.02, phi = 0.33$) and the ability to provide waste data that can be quantified. In relation to paper, food, batteries, glass and cardboard the data submitted by the respondents was tested but proved inconclusive (see Table C-1).

Table C-1: Findings from Chi square test for independence used to determine the associations between recycling and the ability to provide waste data

Business waste	Test	Valid cases (N)	df	P value	Symmetric measure (Phi)	Comments
Plastics	Fisher exact test	63	1	0.006	0.36	Significant
Metal	Fisher's exact test	58	1	0.02	0.33	Significant
Paper & batteries				Not valid		In 25% of cells expected frequencies < 5
Food, glass & cardboard				Not valid		In 50% of cells expected frequencies < 5

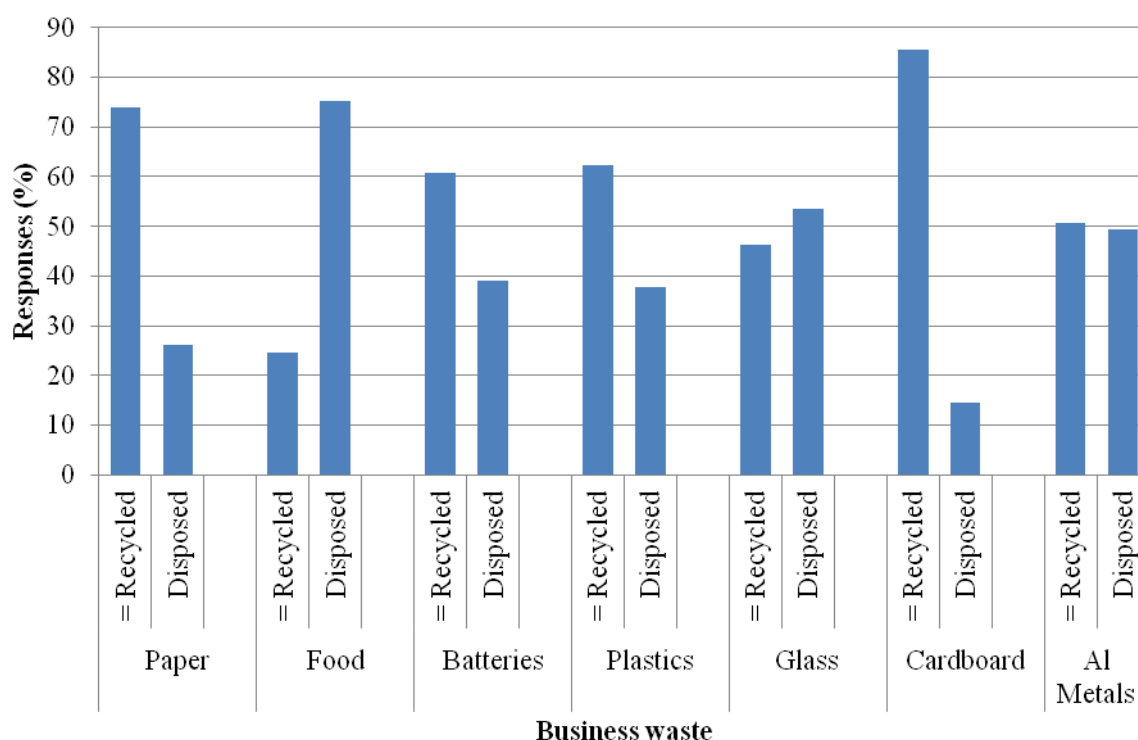


Figure C-6: Responses from service industry SMEs on the disposal of business waste

Reporting of carbon emissions

To gauge the views of respondents a series of questions was asked to obtain their stance on the reporting of carbon emissions and the drivers and barriers to their businesses reporting their emissions. The Marshall Report (1998) has reported that SMEs in the UK contribute to 60% of carbon emissions. When asked however, the respondents underestimated the contribution to the percentage of carbon emissions produced in the UK. A quarter, responded that the carbon emissions produced by SMEs in the UK was 20%; only 6% of businesses acknowledged the extent of carbon emissions as determined by the Marshall Report.

In terms of the size of the business and the percentage of carbon emissions they thought SMEs produced, the findings are represented in Figure C-7. Fifty percent of sole traders, thought SMEs produced less than 10% of carbon emissions in the UK. Of micro businesses, 37% thought SMEs contributed 20% of emissions; small, 24% thought 40% and for medium businesses, 38% viewed SMEs' contributions as being 30% of carbon emissions produced. The majority of the respondents' underestimated SMEs productions of carbon emissions.

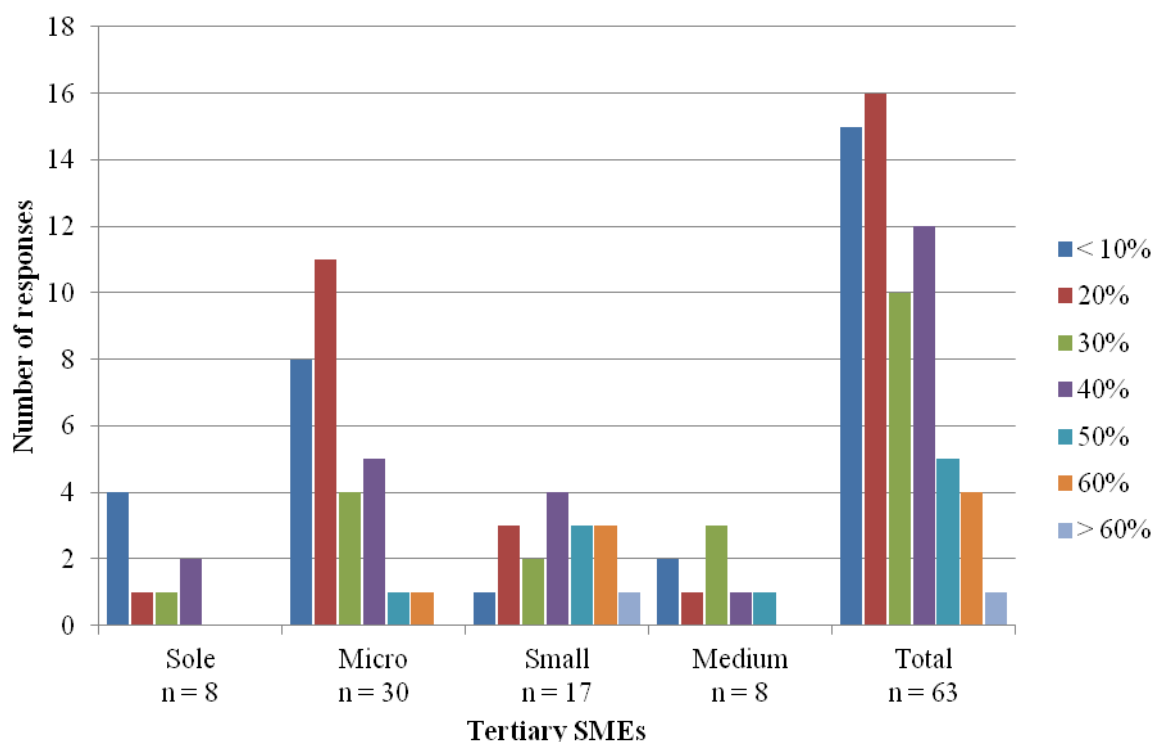


Figure C-7: Responses relative to the scale of the business on the amount of carbon emissions they thought UK SMEs produced

The results represented in Figure 4-7 shows a trend whereby the scale of the business influences the perception in the percentage of carbon emissions produced by a SME. The association between the scale of the businesses and perceived levels of carbon emissions was tested using a Mann-Whitney U Test (Pallant, 2010). The test found there were significant differences between businesses employing fewer than 10 employees ($Md = 20, n = 38$) and those with more than 10 employees but fewer than 250 ($Md = 35, n = 25$) in their perceived amount of carbon emissions produced by SMEs; $U = 269, z = -2.88, p = 0.004, r = 0.36$.

The views of service industry SMEs however, to the researcher's knowledge have not been directly canvassed. The respondents were not in favour of the mandatory reporting of carbon emissions for their sector with 68% against the proposal, 22%, in favour and 10% were uncertain or unsure. The fifteen respondents who favoured the mandatory reporting of carbon emissions for their sector were asked about the reasoning behind their stance. The main reason given by nearly half of the respondents, 47%, was they favoured the mandatory reporting of carbon emissions as it served to demonstrate environmental responsibility. The two other reasons of note was because of the impact of climate change a main reason for 20% of respondents who favoured reporting and because the proposal would enhance skills and improve the knowledge of SMEs. This was seen as a determining reason by 13% of the respondents who favoured mandatory reporting.

The majority of the service industry respondents thought carbon emission reporting should not be made mandatory for SMEs. Reasons behind their responses are indicated in Figure C-8. The three main reasons why they did not want the mandatory reporting of emissions was because of the perceived costs in terms of implementation and maintenance, the poor quality of information and the lack of specialist staff.

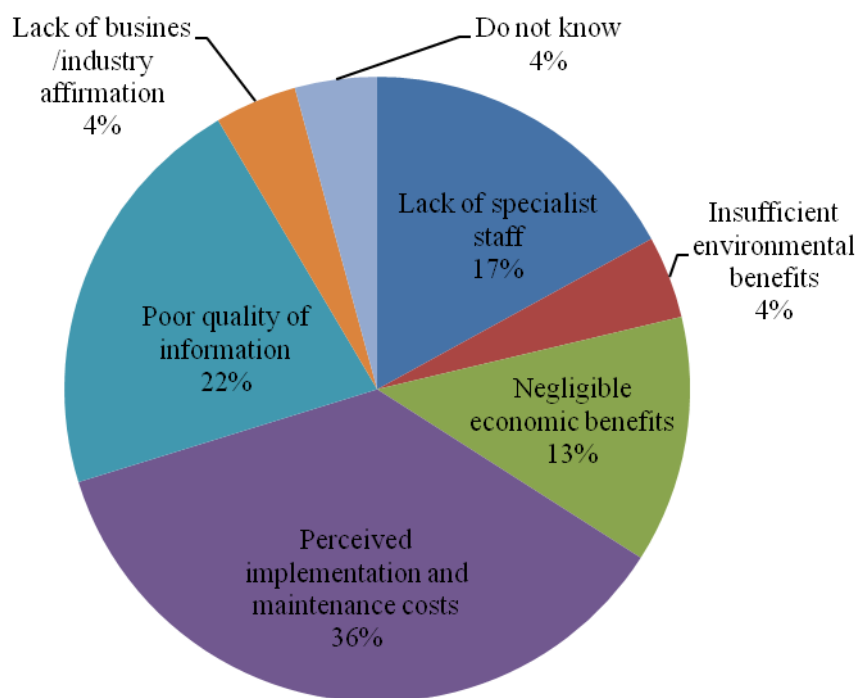


Figure C-8: Responses for the reasons given for those not in favour of the mandatory reporting of carbon emissions

The barriers or reasons against the mandatory reporting of carbon emissions provide an indication as to the difficulties within the sector, enabling solutions to counter the difficulties to be sought and implemented. Alternatively, ‘drivers’ indicate the motivators that would nudge a business towards an action. The ‘drivers’ that would ensure the sector reported carbon emissions were considered. The findings (see Figure C-9) showed there to be sector agreement (*strongly agree and agree*) for three main drivers that would ensure the reporting of carbon emissions. The main drivers are; the risk of prosecution, 74%; government funding and support, 72% and improved environmental performance, 59%. The least effective or persuasive driver to ensure that a business reported their carbon emissions was that it motivated the workforce, with 32% in agreement, an expression of neither agree or disagree by 52% and disagreement by 16% respectively.

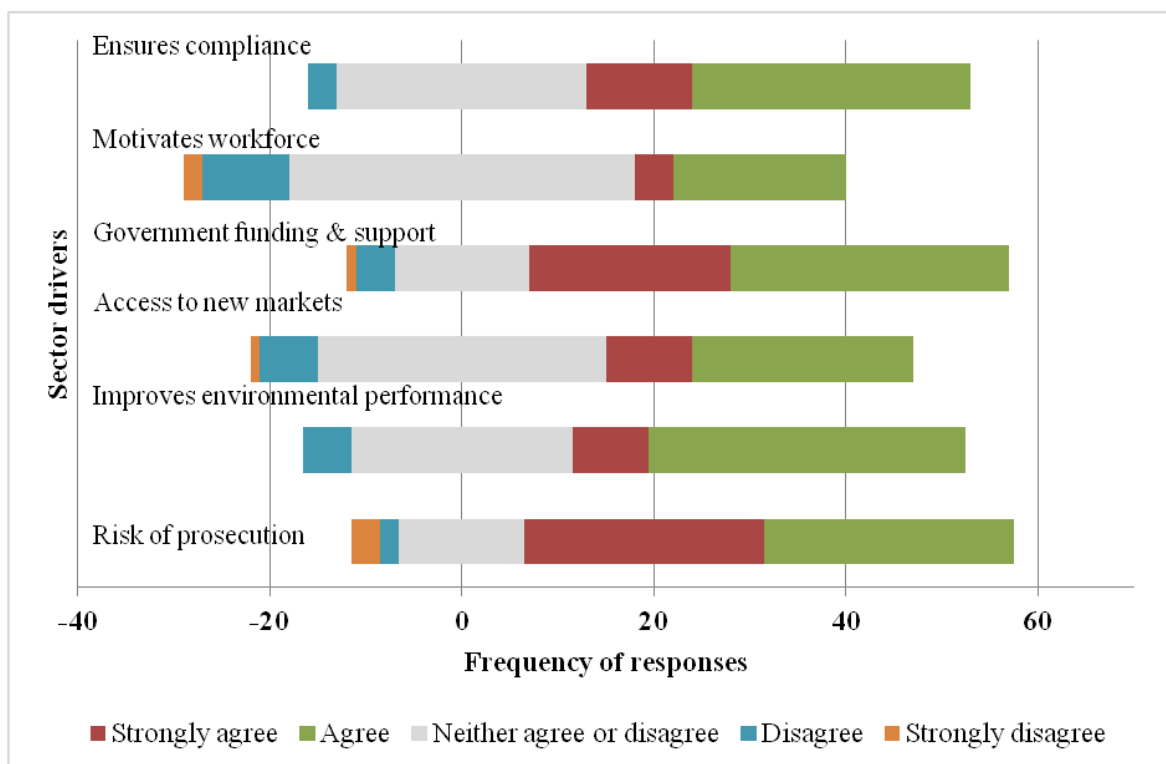


Figure C-9: Responses to drivers that would ensure the reporting to carbon emissions

Summary of findings from the overview

The service industry is characterised by micro businesses that employ one and fewer than ten employees (45%); and trade from rented premises (48%). Over a third of businesses within the sector did not know their annual consumption of electricity (38%) or gas (37%) although, no significant association between the types of the business premises from which the firms traded and providing estimated electricity consumption was found. Renewable energy is not likely to be utilised by the businesses with only 2% of the sector using it as a power source.

The majority of businesses within the sector are likely to undertake business travel by road (52%). The vehicles they use are fuelled by fossil base derivatives (diesel, 63%; petrol, 34%) and greener fuels such as LPG and CNG are not used. Cardboard, is the waste item most likely to be recycled by businesses within this sector (86%) and for the recycling of plastics and metals there was a significant association between these items and providing figures on recycling.

The size of the business influences the respondent's perception on the amount of carbon emissions produced by the sector. The majority of owner-managers within the sector were not in favour of mandatory reporting (68%) because of the perceived costs of implementation and maintenance, which was considered the main 'barrier' by over a third of respondents (36%) however, the main 'driver' which would ensure their businesses reported emissions was the risk of being prosecuted (74%).

Appendix D

Packing Company

Table 5-1: Data used in the inventory for the packing, packaging and delivery service for a picture

Packaging & delivery service	Component	Processes & materials	Database/library	Data ² (parameters & measurements)
Picture	Desktop computer	Desktop computer, without screen, (GLO)		0.00066 (p)
	Computer mouse; optical with cable	Mouse device, optical, with cable, (GLO)		0.00066 (p)
	Mail_Box_Inc_printer	MAILBOX_ INC printer, laser jet, colour, (GLO); <i>(toner accounted for in printer 24 toners over 10 years)</i>		0.00066 (p)
	Weigh scales	X6CrNi18 (~304) I (stainless steel casing) G-AlMg3 (242) I (aluminium sub-frame)	IDEMAT 2001 IDEMAT 2001	0.00066 (p)
	Keyboard	Keyboard, standard version, (GLO)		0.00066 (p)
	CRT screen	17 inch screen, (GLO)		0.00066 (p)
	Energy use	(see Table 5-2.)		(see Table 5-2.)
	Weigh-bills	Uncoated woodfree paper, (regional storage)		0.012
	Client shipping form	Uncoated woodfree paper, (regional storage)		0.0046
	Storage records	Uncoated woodfree paper, (regional storage)		0.0046
	Transport	(see Table 5-3.)	-	(see Table 5-3)
	Low tack masking tape (composite material)	Kraft paper, unbleached		0.0083 kg
	Masking tape (adhesive)	Urea formaldehyde resin,		0.00044 kg
	Packing tape	Polypropylene, (granulate)		0.00514
	Fragile packing tape	Polypropylene, (granulate)		0.00477

Packaging & delivery service	Component	Processes & materials	Database/library	Data ² (parameters & measurements)
	MBE scotch tape	Polypropylene, (granulate)		0.00257
	Bubble wrap	Polyethylene, LDPE, (granulate)		0.089
	Foam sheet	General purpose polystyrene, (GPPS)		0.037
	Card sheet	Kraft paper, unbleached		0.36
	Hard board	Wood board	ETH-ESU 96	1.31
	Polystyrene blocks	General purpose polystyrene, (GPPS)		0.08
	Polystyrene peanuts	Polystyrene, (GPPS)		0.48
	Art Box (Packaging)	Single walled, corrugated mixed fibre board		0.79
Waste treatment & disposal	Waste	Packaging card for incineration (20%), (CH) Solid waste to landfill (80%), (CH)		10g

(¹ Unless otherwise specified to the contrary, Ecoinvent (2007) database used; materials where appropriate derived from the plant; and where available European averages employed)

(² Quantities or usage, primary data from the enterprise, unless stated to the contrary)

Table 5-2: Energy used by the service to pack and package a picture

Electrical office equipment/space heating	Operational mode specifications	User mode	Process energy consumption (kWh) (UK energy mix)
Computer	Operational: 90W Standby: 2W	90W, 0.5 hours (<i>on</i>); 2W, 7 hours (<i>standby</i>)	0.06
Monitor	Operational: 30W; Standby: 2W	30W, 0.5 hours (<i>on</i>); 2W, 7 hours (<i>standby</i>)	0.03
Printer	Operational: 295W; Standby: 8W	295W, 0.5 hours (<i>on</i>); 8W, 7 hours (<i>standby</i>)	0.20
Weigh scales	Operational: 72W; Standby: n/a	72W, 7.5 hours (<i>on</i>)	0.54
Lighting (T4) (fluorescent strip) (x3)	Operational: 16W; Standby: n/a	16W, 7.5 hours (<i>on</i>)	0.36
Heating	-	-	0 (ambient)
Bar code (printing)	Operational: 125W; Standby: 9W	125W, 0.02 hours (<i>on</i>) 9W, 7.48 hours	0.07

(N.B. Based upon a 7.5-hour working day & data type for operational modes primary and from the enterprise)

Table 5-3: Contribution made by transport to the packing, packaging and delivery of the service

Mode of transport ¹	Route/destination	Shipping distances (km)	
		Road	Air
Van (< 3.5t)	Auction house - packaging site	2.9	-
DHL courier (lorry; 3.5-16t)	Bath – East Midland Airport	225.31	-
Aircraft freight: (intercontinental)	East Midlands (UK) – JFK Airport (USA)	-	5445
DHL courier (lorry; 3.5-16t)	JFK – DHL depot (Massachusetts)	349	-
Lorry 21t : (CH), (transport, municipal waste collection)	Enterprise – Waste transfer station	9.98	-

Film Company

Table 5-4: Data used in the inventory to model the filming and production of an eight-minute documentary

Stage	Component	Main processes/materials used & quantities ¹	Database/library	Life period (years)	Data parameters /measurements
Pre-Production					
	Office laptop	Laptop computer (GLO)		3	0.0185 (p)
	Office printer	Laser jet colour printer (GLO)		5	0.0111 (p)
	Office stationary (paper and envelopes)	Woodfree coated paper, (regional storage)		-	0.018 (kg)
	Office telephone	Acrylonitrile-butadiene-styrene copolymer, ABS (0.2285 kg) Chromium steel 18/8, (0.841 kg) Printed wiring board, mixed mounted, unspec., solder mix (GLO) (0.0716 kg)		6	0.0093 (p)
	Office water	Tap water at user		-	0.15kg
	Meeting clients	Petrol passenger car		-	117 personkm
	Location visits	Transport, van <3.5t		-	0.491604 tkm
	Pre-production electricity usage	UK energy mix		-	see Table 5-5
	Pre- production heating	Natural gas, at boiler condensing modulating < 100kW		-	see Table 5-5
Production					
	Camcorder	Polycarbonate, (1.98 kg) Uncoated flat glass, (0.20 kg) Electronic component, active, unspecified (GLO) (0.02 kg)		3	0.0185 (p)
	Rechargeable battery	Battery, LiIo, rechargeable, prismatic, (/GLO) (0.222 kg)		2	0.0278 (p)
	Battery charger	Acrylonitrile-butadiene-styrene copolymer, ABS (0.361 kg) Electronic component, active, unspecified (GLO) (0.039 kg)		2	0.0278 (p)
	Tripod	Aluminium, production mix, (3.2 kg)		8	0.00694 (p)
	PAGLight	Float glass uncoated ETH S (0.2 kg) Acrylonitrile-butadiene-styrene copolymer, ABS, (0.8 kg)	ETH-ESU	3	0.0185 (p)
	Microphone	Printed wiring board, mixed mounted, unspec., solder mix, (GLO) (0.013 kg)		1	0.0556 (p)

Stage	Component	Main processes/materials used & quantities ¹	Database/library	Life period (years)	Data parameters /measurements
	Windshield	Acrylonitrile-butadiene-styrene copolymer, ABS, (0.052 kg) PUR rigid foam A (0.224 kg) Acrylonitrile-butadiene-styrene copolymer, ABS, (0.028 kg) Nylon 66 E (0.028 kg)	Industry data	1	0.0556 (p)
	Microphone cable	Cable, ribbon cable, 20-pin, with plugs (GLO) (0.077 kg)		1	0.0556 (p)
	Headphones	Acrylonitrile-butadiene-styrene copolymer, ABS (0.27 kg) PUR flex. block foam I (0.01 kg) Printed wiring board, mixed mounted, unspec., solder mix (GLO) (0.02 kg)	IDEMAT 2001	1	0.0556 (p)
	Boom pole	Aluminium, production mix, at plant (0.94 kg)		6	0.0093 (p)
	Mini DV tapes	Acrylonitrile-butadiene-styrene copolymer, ABS,(0.03 kg) Polyethylene terephthalate, granulate, amorphous, (0.01 kg)		-	0.8 kg (20 tapes)
	Office consumables	Paper, woodfree, uncoated (regional storage)		-	0.004 kg
	Production electricity usage	UK energy mix	-	-	see Table 5-5
	Transporting equipment: studio to location	Transport, van <3.5t		-	0.79422 tkm
Post-Production					
	Edit computer	Computer, without screen (GLO)		3	0.0185 (p)
	Flat screens (x2)	17 inch LCD screen (GLO)		5	0.0111 (p)
	Keyboard	Standard version keyboard (GLO)		5	0.0111 (p)
	Mouse	Accessory; optical, with cable (GLO)		3	0.0185 (p)
	Speakers	Wood board (5.2 kg)	ETH-ESU	6	0.0093
	Mini DV deck	Acrylonitrile-butadiene-styrene copolymer, ABS, (2.16 kg) Integrated circuit, IC, logic type (GLO) (0.27 kg) Integrated circuit, IC, memory type (GLO) (0.27 kg)		6	0.0093 (p)
	Office support	Coated woodfree paper, at regional storage		-	0.011 kg
	Office water	Tap water, at use		-	2.25kg

Stage	Component	Main processes/materials used & quantities ¹	Database/library	Life period (years)	Data parameters /measurements
	Post production electricity usage	UK energy mix		-	see table 8-2
	Post production gas usage	Natural gas, at boiler condensing modulating < 100kW		-	See table 8-2
	Transport (<i>project employees I</i>)	Diesel passenger car		-	68 personkm
	Transport (<i>project employee II</i>)	Diesel passenger car		-	19 personkm
	Transport (<i>project employee III</i>)	Diesel passenger car		-	13 personkm
	Waste	Municipal waste collection lorry, 21t (CH)		-	9.98 km
		Disposal, municipal solid waste, landfill (CH) (80%)		-	0.02 kg
		Disposal, municipal incineration (CH) (20%)			

(¹ Unless specified to the contrary, Ecoinvent (2007) database used; materials where appropriate derived from the plant; and where available European averages employed)

(² Quantities or usage, primary data from the enterprise, unless stated to the contrary)

Table 5-5: Data used in the inventory to model the energy used in the filming and production of an eight-minute documentary

Stage	Equipment	Operational mode specifications	User mode	Process energy consumption (kWh)
Pre-production				
Office support (7.5 hours)	Laptop	Operational: 12W Standby: 7W	12W, 7 hours (on); 7W, 0.5 hours (standby)	0.09
	Printer	Operational: 300W Standby: 4W	300W, 1 hour (on); 4W, 6.5 hours (standby)	0.33
	Telephone	Operational: 0.026kWh for ~3 minutes	~9 minutes	0.078
	Office lighting & residual electrical equipment	Operational: 7.5 hours	Average per day	10.45 (<i>excluding equipment support</i>)
	Gas heating	Operational: 7.5 hours	Average per day	53
Production				
Office support (4 hours over 4 days)	Laptop	Operational: 12W Standby: -	12W, 4 hours (on)	0.048
	Printer	Operational: 300W	300W, 4 hours (on)	1.2
	Telephone	Operational: 0.026kWh for ~3 minutes	~5 minutes	0.04
	Battery charger	Operational: 18W	18W, 20 hours (on)	0.36
	Office lighting & residual electrical equipment	Operational: 11kWh/day	Half a day (~4 hours)	3.85(<i>excluding equipment support</i>)
Post-production				
(5 days of studio working)	Edit Computer	Operational: 38W	38W, 25 hours (on)	0.95
	Speakers	Operational: 22W	22W, 25 hours (on)	0.55
	Mini DV Deck	Operational: 15W	15W, 6 hours (on)	0.09
	Screens (x2)	Operational: 65W	65W, 25 hours (on))	3.25
	Laptop	Operational: 12W	12W, 12.5 hours (on)	0.15
	Telephone	Operational: 0.026kWh for ~3 minutes	~28 minutes	0.24
	Printer	Operational: 300W Standby: 4W	300W, 1 hour (on); 4W, 24 hours (standby)	0.40
	Office support (<i>electricity & gas</i>)	Operational: electricity 1.8kWh/FTE Operational: gas 8.83kWh/FTE	3.5 FTE	6.3 kWh/FTE 31 kWh/FTE
	Studio project staff (<i>electricity& gas</i>)	Operational: electricity 11kWh/day Operational: gas 53kWh/day	5 days	50 (<i>excluding studio process electricity</i>) 265

Online Distance Learning Company

Table 5-6: Data used in the inventory to model the distance learning online HND business course

Activities	Component	Main processes/materials used & quantities	Database/library	Life period (years)	Data parameters /measurements
Home based					
Student	Computer	Desktop computer, no screen, (GLO)		3	0.666 (p)
	Flat screen monitor	17 inch LCD screen, (GLO)		5	0.4 (p)
	Printer	Colour laser jet printer, (GLO)		8	0.25 (p)
	Computer mouse	Optical device with cable, (GLO)		3	0.666 (p)
	Computer keyboard	Standard version keyboard, (GLO)		5	0.4 (p)
	Paper for draft assignments	Uncoated woodfree paper, (regional storage)		-	0.6kg
	Desk	Particle board, used indoors, (0.54m ³)		10	0.2 (p)
	Chair	Steel ETH S, (0.1kg) Leather I, (0.0011m ²) PUR flex. block foam I, (0.11kg) PVC B250, (0.66kg)	ETH-ESU 96 IDEMAT 2001 IDEMAT 2001 BUWAL 250	5	0.4 (p)
	Telephone	ABS A, (0.23kg) Steel, converter, chromium steel 18/8, (0.84kg) Printed wiring board, mixed mounted, unspec., solder mix, (0.07kg)		8	0.3 (p)
	Energy used by the student	see Table 5-8	-	-	see Table 5-8
Tutor	Computer	Desktop computer, no screen, (GLO)		3	0.009 (p)
	Flat screen monitor	17 inch LCD screen, (GLO)		5	0.005 (p)
	Computer mouse	Optical device with cable, (GLO)		3	0.009 (p)
	Computer keyboard	Standard version keyboard, (GLO)		5	0.005 (p)
	Desk	Particle board, used indoors, (0.54m ³)		10	0.003 (p)
	Chair	Steel ETH S (0.1kg) Leather I, (0.0011m ²) PUR flex. block foam I, (0.11kg) PVC B25,0 (0.66kg)	ETH-ESU 96 IDEMAT 2001 IDEMAT 2001 BUWAL 250	5	0.005 (p)
	Telephone	ABS A, (0.23kg) Steel, converter, chromium steel 18/8, (0.84kg) Printed wiring board, mixed mounted, unspec., solder mix, (GLO), (0.07kg)		8	0.003 (p)

Activities	Component	Main processes/materials used & quantities	Database/library	Life period (years)	Data parameters /measurements
	Travel undertaken by the tutor	see Table 5-7	-	-	see Table 5-7
	Energy used by the tutor	see Table 5-8	-	-	see Table 5-8
Local based	Computers (x3)	Desktop computers, no screens, (GLO)		3	0.0007 (p)
Office facility	Flat screen monitors (x3)	17 inch LCD screen, (GLO)		5	0.0004 (p)
	Computer keyboards (x3)	Standard version keyboards, (GLO)		5	0.0004 (p)
	Computer mice (x3)	Optical device with cables, (GLO)		3	0.0007 (p)
	Printer & toner module	Colour laser jet printer, (GLO)		8	0.0003 (p)
	Paper used for HND course	Uncoated, woodfree paper, (regional storage)			0.6kg
	Desks (x3)	Particle board, used indoors, (0.54m ³) Steel ETH S, (0.1kg)	ETH-ESU 96	10	0.0002 (p)
	Chairs (x3)	Leather I, (0.0011m ²) PUR flex. block foam I, (0.11kg) PVC B250, (0.66kg)	IDEMAT 2001 IDEMAT 2001 BUWAL 250	5	0.0004 (p)
	Telephone	ABS A, (0.23kg) Steel, converter, chromium steel 18/8, (0.84kg) Printed wiring board, mixed mounted, unspec., solder mix (GLO), (0.07kg)		5	0.0004 (p)
	Office air purifier	Glass fibre reinforced plastic, polyester resin, hand lay-up, ((1kg) ABS I, (3kg) G-AlSi8Cu3 (380) I, (2kg)	IDEMAT 2001 IDEMAT 200	5	0.0004 (p)
	Office coffee machine	Polystyrene, GPPS, (1kg) Uncoated flat glass, (0.9kg) Aluminium alloy, AlMg3, (0.1kg) Steel, converter, chromium steel 18/8, (0.3kg) Uncoated woodfree paper, (regional storage), (0.9kg)		5	0.0004 (p)
	Office fridge	Cast iron, at plant, (8kg) ABS A, (6kg) Copper, (regional storage), (0.6kg)	Industry data	8	0.0003 (p)
	Office microwave	Steel, converter, chromium steel 18/8, (15kg) Uncoated flat glass, (1kg) Alkyd paint, white, 60% in H2O, (1kg) Mineral wool ETH S (0.2kg)	ETH-ESU 96	8	0.0003 (p)

Activities	Component	Main processes/materials used & quantities	Database/library	Life period (years)	Data parameters /measurements
	Office kettle	PP granulate average B250, (0.22kg) PVC (b) I, (0.15kg) X6CrNi18 (~304) I, (0.45kg) Cu-E I, (0.03kg)	BUWAL 250 IDEMAT 2001 IDEMAT 2001 IDEMAT 2001	3	0.0007 (p)
	Office electric heaters (x3)	Polycarbonate, (9kg) X6CrNi18 (~304) I, (9kg) Aluminium, primary, (3kg)		8	0.0003 (p)
	Office water	Tap water, at user			0.06kg/student
	Waste treatment and disposal	Municipal solid waste, 22.9% water, to sanitary landfill (CH) Municipal waste collection, lorry 21t (CH)			0.04kg/student 132km
	Travel	see Table 5-7	-	-	see Table 5-7
	Office processes & energy	see Table 5-8	-	-	see Table 5-8
Regional based	Travel	see Table 5-7	-	-	see Table 5-7
Network based	Energy processes	see Table 5-8	-	-	see Table 5-8

(¹ Unless otherwise specified to the contrary, Ecoinvent (2007) database used; materials where appropriate derived from the plant; and where available European averages employed)

(² Quantities or usage, primary data from the enterprise, unless stated to the contrary)

Table 5-7: Contribution made by transport to the overall service boundary

Activities	Mode of transport	Distance (km) (average/working day)	User mode	Values (personkm/student)
Home based	Passenger car (x2)(CH)	17.38; 11.26	450 days;	7.81; 5.07
	Bus (x1)(CH)	12.23	1002 students	5.49
Regional based	Regional train (MD) (CH)	1023.54	1002 students	1.02
	Regional train (office staff) (CH)	1023.54		1.02
	Regional train (course auditor) (CH)	592	1002 students	0.59
	Regional train (tutor) (CH)	758		0.76

Table 5-8: Energy used within the overall service boundary

Activities	Electrical office equipment/space heating	Operational mode specifications	User mode	Process energy consumption (kWh) (UK energy mix)
Home based				
Student	Student desktop computer	Operational: 190W	190W, 1040 hours (<i>on</i>);	197.56kWh (<i>excludes emails</i>)
	Student monitor	Operational: 19W	19W, 1040 hours (<i>on</i>); 2W, 7 hours (<i>standby</i>)	19.76kWh
	Student printer	Operational: 350W	350W, 0.083 hours (<i>on</i>);)	0.03kWh
	Student lighting	Operational: task light 60W; main lighting 75W	60W, 1040 hours (<i>on</i>) 75W, 1040 hours (<i>on</i>)	62.4kWh 78kWh
	Emails	Operational: 0.0009kWh (<i>per email</i>)	48 (<i>based upon average number of emails sent by tutors</i>)	0.04kWh
	Telephone call at beginning of course to tutor	Operational: 0.026kWh (<i>per 3 minutes of call time</i>)	15 minutes	0.13kWh
	Heating	Operational: 1.88kWh energy (<i>spent from power consumption for an hour</i>)	468 hours	3167.42MJ
Tutor	Tutor desktop computer	Operational: 190W	190W, 16 hours (<i>on</i>)	3kWh (<i>excludes emails</i>)
	Tutor monitor	Operational: 19W	19W; 16 hours (<i>on</i>)	0.30kWh
	Emails	Operational: 0.0009kWh (<i>per email</i>)	Students: 48 Office emails 24 related to 75 students	0.04kWh 0.0003kWh
	Telephone call to student	Operational: 0.026kWh (<i>per 3 minutes of call time</i>) (<i>beginning of the second year</i>)	15 minutes	0.13kWh
	Tutor lighting	Operational: 60W; 75W	60W; 16 hours (<i>on</i>) 75W; 16 hours (<i>on</i>)	0.96kWh 1.2kWh
	Heating	Operational: 1.88kWh	8 hours	54.14MJ
	Moodle	Operational: 500W	0.50W; 1040 hours	0.52kWh
Network based				
	Website	Operational: 850W	0.85W; 17472 hours	14.85kWh
Local based				
	Office computers (x3)	Operational: 250W Standby: 6W	250W; 6.5 hours 6W; 1 hour (<i>based upon the average working day for 2 years: 450 days and the numbers of student doing courses: 1002</i>)	2.18kWh (<i>excludes emails sent from the office to the tutor and student</i>)

Activities	Electrical office equipment/space heating	Operational mode specifications	User mode	Process energy consumption (kWh) (UK energy mix)
	Office monitors (x3)	Operational: 72W Standby: 15W	72W; 6.5 hours 15W; 1 hour <i>(based upon the average working day for 2 years: 450 days and the numbers of student doing courses: 1002)</i>	0.65kWh
	Office printing	Operational: 35W	35W; 5 minutes	0.003kWh
	Office emails to tutors	Operational: 0.0009kWh per email	24 administration emails related to 75 students	0.0003kWh
	Office telephone calls to tutor	Operational: 0.026kWh per 3 minutes of call time	240 minutes related to 75 students	0.03kWh
	Office courtesy call to student	Operational: 0.026kWh per 3 minutes of call time	10 minutes	0.09kWh
	Office air purifier	Operational: 6W	6W; used for 3780 hours for 504 working days related to 1002 students	0.02kWh
	Office coffee machine	Operational: 1.3kW	250ml 1 minute to boil time; 504 working days; average on one cup per day; 504 minutes; 8.4 hours; related to 1002 students	0.01kWh
	Office fridge	Operational: 137kWh annually	2 years related to 1002 students	0.27kWh
	Office microwave	Operational: 700W	700W; 1.4min/day; 504 days; ~706 minutes; ~12 hours; 1002 students	0.008kWh
	Office kettle	Operational: 2.2kW	2.2kW; 2 minutes/day; 504 days; 1008 minutes; 16.8 hours; related to 1002 students	0.036kWh
	Office heating electric panel heaters (x3)	Operational: 2000W	2000W; 14 months of heating; 21 working days per month; 294 days; 7.5 hours per day; 2205 hours; related to 1002 students	13.20kWh
	Office lighting	Operational: 65W up lighters (x2); 18W light bulbs (x14)	(2) 65W; 3780 hours; related to 1002 students (14) 18W; 3780 hours related to 1002 students	0.49kWh 0.95kWh

Appendix E

Table 6-1: Characterised and normalised results for the service to pack and deliver a picture from the auction house to its collection hub in the USA - ReCiPe at midpoint level (H) (E)

Impact category	Characterised data (overall service boundary)	Normalised impacts (overall service boundary)	Characterised data (service boundary)	Normalised impacts (service boundary)
Climate change	2.87E+01kg CO ₂ eq	2.56E-03	2.74E+01kg CO ₂ eq	2.44E-03
Ozone depletion	3.86E-06kg CFC-11 eq	1.75E-04	3.85E-06kg CFC-11 eq	1.75E-04
Terrestrial acidification	1.23E-01kg SO ₂ eq	3.57E-03	1.23E-01kg SO ₂ eq	3.55E-03
Freshwater eutrophication	5.75E-04kg P eq	2.28E-03	4.96E-04kg P eq	1.97E-03
Marine eutrophication	3.08E-02kg N eq	2.48E-03	1.84E-02kg N eq	1.49E-03
Human toxicity	2.07E+00kg 1,4-DB eq	3.46E-03	1.03E+00kg 1,4-DB eq	1.71E-03
Photochemical oxidant formation	1.55E-01kg NMVOC	2.74E-03	1.53E-01kg NMVOC	2.71E-03
Particulate matter formation	4.34E-02kg PM ₁₀ eq	2.91E-03	4.31E-02kg PM ₁₀ eq	2.89E-03
Terrestrial ecotoxicity	2.94E-03kg 1,4-DB eq	3.58E-04	2.91E-03kg 1,4-DB eq	3.55E-04
Freshwater ecotoxicity	7.59E-02kg 1,4-DB eq	7.01E-03	2.55E-02kg 1,4-DB eq	2.35E-03
Marine ecotoxicity	7.78E-02kg 1,4-DB eq	9.49E-03	3.31E-02kg 1,4-DB eq	4.04E-03
Ionising radiation	2.69E+00kg U235 eq	4.30E-04	2.66E+00kg U235 eq	4.26E-04
Agricultural land occupation	4.53E+00m ² a	1.00E-03	4.53E+00m ² a	1.00E-03
Urban land occupation	2.15E-01m ² a	5.28E-04	2.06E-01m ² a	5.04E-04
Natural land transformation	1.41E-02m ²	8.69E-02	1.41E-02m ²	8.73E-02
Water depletion	1.01E-01m ³	-	9.91E-02m ³	-
Metal depletion	7.70E-01kg Fe eq	1.08E-03	7.65E-01kg Fe eq	1.07E-03
Fossil depletion	1.13E+01kg oil eq	5.96E-03	1.13E+01kg oil eq	5.95E-03

Table 6-2: Characterised and normalised results for the service to shoot, produce and edit one minute of filmed documentary - ReCiPe at midpoint level (H) (E)

Impact category	Characterised data (overall service boundary)	Normalised impacts (overall service boundary)	Characterised data (service boundary)	Normalised impacts (service boundary)
Climate change	4.80E+01kg CO ₂ eq	4.27E-03	3.87E+01kg CO ₂ eq	3.44E-03
Ozone depletion	3.81E-06kg CFC-11 eq	1.73E-04	3.77E-06kg CFC-11 eq	1.71E-04
Terrestrial acidification	7.23E-02kg SO ₂ eq	2.10E-03	6.97E-02kg SO ₂ eq	2.02E-03
Freshwater eutrophication	7.30E-04kg P eq	2.90E-03	6.59E-04kg P eq	2.62E-03
Marine eutrophication	1.93E-02kg N eq	1.55E-03	1.25E-02kg N eq	1.01E-03
Human toxicity	2.43E+00I,4-DB eq	4.06E-03	1.17E+00kg I,4-DB eq	1.95E-03
Photochemical oxidant formation	5.91E-02kg NMVOC	1.05E-03	5.46E-02kg NMVOC	9.66E-04
Particulate matter formation	2.36E-02kg PM10 eq	1.58E-03	2.26E-02kg PM10 eq	1.51E-03
Terrestrial ecotoxicity	2.02E-03kg I,4-DB eq	2.46E-04	1.83E-03kg I,4-DB eq	2.24E-04
Freshwater ecotoxicity	1.03E-01kg I,4-DB eq	9.56E-03	3.86E-02kg I,4-DB eq	3.57E-03
Marine ecotoxicity	1.01E-01kg I,4-DB eq	1.23E-02	4.57E-02kg I,4-DB eq	5.58E-03
Ionising radiation	5.16E+00kg U235 eq	8.26E-04	5.08E+00kg U235 eq	8.14E-04
Agricultural land occupation	2.52E-01m ² a	5.56E-05	2.48E-01m ² a	5.48E-05
Urban land occupation	3.36E-01m ² a	8.22E-04	3.29E-01m ² a	8.06E-04
Natural land transformation	6.85E-03m ²	4.23E-02	6.80E-03m ²	4.20E-02
Water depletion	1.22E-01m ³	-	1.16E-01m ³	-
Metal depletion	2.60E+00kg Fe eq	3.64E-03	2.58E+00kg Fe eq	3.62E-03
Fossil depletion	9.50E+00kg oil eq	5.00E-03	9.39E+00kg oil eq	4.94E-03

Table 6-3: Characterised and normalised results for providing and performing an online distance learning Level 5 HND Business Management course over a 24-month period for one UK student studying part-time based at home - ReCiPe at midpoint level (H) (E)

Impact category	Characterised data (overall service boundary)	Normalised impacts (overall service boundary)
Climate change	2.53E+03kg CO ₂ eq	2.24E-01
Ozone depletion	7.99E-05kg CFC-11 eq	3.58E-03
Terrestrial acidification	3.10E+00kg SO ₂ eq	8.88E-02
Freshwater eutrophication	6.13E-02kg P eq	2.43E-01
Marine eutrophication	1.25E+00kg N eq	9.83E-02
Human toxicity	9.77E+01kg 1,4-DB eq	1.60E-01
Photochemical oxidant formation	2.23E+00kg NMVOC	3.82E-02
Particulate matter formation	1.09E+00kg PM10 eq	7.16E-02
Terrestrial ecotoxicity	1.14E-01kg 1,4-DB eq	1.39E-02
Freshwater ecotoxicity	3.10E+00kg 1,4-DB eq	2.77E-01
Marine ecotoxicity	3.53E+00kg 1,4-DB eq	4.19E-01
Ionising radiation	2.45E+02kg U235 eq	3.91E-02
Agricultural land occupation	6.06E+01m ² a	1.34E-02
Urban land occupation	1.58E+01m ² a	3.85E-02
Natural land transformation	2.03E-01m ²	1.24E+00
Water depletion	7.48E+00m ³	-
Metal depletion	3.13E+02kg Fe eq	4.38E-01
Fossil depletion	2.80E+02kg oil eq	1.46E-01